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Aerodynamic Influence Coefficients from Piston Theory: Analytical Development and Computational Procedure

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Prepared for COMMANDER SPACE SYSTEMS DIVISION
UNITED STATES AIR FORCE
Inglewood, California

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ABSTRACT

In this report we present a method for calculating the aerodynamic influence coefficients (AICs) based on third-order piston theory with an optional correction to agree with Van Dyke's quasi-steady second-order theory. The AICs are computed assuming the airfoil to have a rigid chord with or without a (rigid chord) control surface. The influence coefficients relate the surface deflections to the aerodynamic forces through the following definitions. In the oscillatory case,

$$\{F\} = \rho\omega^2 b_r^2 s [C_h] \{h\}$$

and in the steady case,

$$\{F_s\} = (1/2)\rho V^2 (S/\bar{c}) [C_{hs}] \{h\}$$

The piston theory is limited to high Mach number (or high reduced frequency), but Van Dyke's quasi-steady correction extends the validity to some lower supersonic Mach number at low reduced frequency.

The Aerospace IBM 7090 Computer Program Number HM11 provides the AICs from this theory in both a printed and an optional punched-card output format. The program capacity is 25 surface strips, 15 Mach numbers, and 20 reduced velocities for each Mach number.

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SYMBOLS

a_o	Ambient speed of sound
b	Local semichord
b_r	Reference semichord
C_h	Element of oscillatory aerodynamic influence coefficient matrix
C_{hs}	Element of steady aerodynamic influence coefficient matrix
C_n	Coefficients in expressions for pressure coefficient
C_p	Pressure coefficient
c	Local chord
c_a	Control surface chord
$\bar{c}$	Mean aerodynamic chord
d	Distance between forward and aft control points
F	Control point force
g	Airfoil semithickness
g_x	Slope of airfoil, $g_x = dg/dx$
h	Vertical deflection
I_n, J_n	Thickness integrals
K_n	Coefficients in expressions for oscillatory aerodynamic coefficients
k	Local reduced frequency, $k = \omega b/V$
k_r	Reference reduced frequency
$L_{h_o}, L_{\alpha_o}, L_{\beta_o}$	Oscillatory leading edge lift coefficients

L_o	Lift referred to leading edge motion
M	Free stream Mach number
$M_{h_o}, M_{\alpha_o}, M_{\beta_o}$	Oscillatory leading edge pitching moment coefficients
M_o	Pitching moment about leading edge referred to leading edge motion
p	Surface pressure; p_o is ambient pressure
q	Free stream dynamic pressure
r_h, r_t	Ratios of hinge-line and trailing-edge thicknesses to maximum thickness, respectively
S	Wing area
s	Wing semispan
$T_{h_o}, T_{\alpha_o}, T_{\beta_o}$	Oscillatory leading edge hinge moment coefficients
T_o	Hinge moment referred to leading edge motion
t_{max}	Airfoil maximum thickness
V	Free stream velocity
$V/b_r\omega$	Reference reduced velocity, $V/b_r\omega = 1/k_r$
v	Unsteady component of downwash velocity
w	Downwash velocity
x	Chordwise coordinate; x_o is coordinate of pitching axis; x_m is coordinate of maximum thickness point; x_h is coordinate of hinge line
α	Angle of attack; α_o is initial angle of attack
β	Control surface incidence; also, $\beta = (M^2 - 1)^{1/2}$
γ	Specific heat ratio of air, $\gamma = 1.400$
Δy	Strip width

Λ	Leading edge sweep angle
ξ	Dimensionless chordwise coordinate, $\xi = x/c$
ρ	Free stream density
τ, τ_h, τ_t	Airfoil thickness ratios at point of maximum thickness, hinge line, and trailing edge, respectively
ω	Circular frequency
$(\bar{\ })$	Bar denotes term depends on flow characteristics normal to leading edge
$[\ ]$	Square matrix
$\{\ \}$	Column matrix

SECTION I

FORMULATION OF THE PROBLEM

A. Introduction

The pressure on a lifting surface is normally given by a surface functional relationship. However, in the limit of a high Mach number (or high reduced frequency), this relationship becomes a point function. As a consequence of this limit, aerodynamic influence coefficients (AICs) may be specified exactly by a strip theory, and control surface and camber effects may be determined in a straightforward manner.

The present formulation derives the AICs from third-order piston theory for a lifting surface with control surface (both assumed rigid in the chordwise direction; i.e., no camber is presently considered). The derivation differs only slightly from that of Ashley and Zartarian[1] in that in the present case the third-order pressure coefficient is generalized to account for sweep and steady angle of attack, and, following a suggestion of Morgan, Huckel, and Runyan,[2] a correction (optional) is suggested to give agreement with the second-order quasi-steady supersonic theory of Van Dyke.[3] This quasi-steady correction should extend the validity of the piston theory to lower supersonic Mach numbers at low reduced frequencies. The derivation given here is taken from Ref. 4; further, the computational aspects of the present report are an extension of the computing procedure of Ref. 4.

B. Sign Convention

The flutter sign convention is used in the oscillatory case: forces and deflections are positive down; rotations are positive with leading edge up. The aerodynamic sign convention is used in the steady case: forces and deflections are positive up; rotations are positive with leading edge up.

C. Derivation of Equations

We quote here the development of Miles[5] in obtaining the piston theory pressure coefficient. There are two cases of interest. The first assumes that the angle of attack is small enough that there are pressure perturbations on the expansion side of the surface. The second assumes that the angle of attack is large, and that the expansion pressure approaches a vacuum and is ineffective in producing perturbations. Because of the difficulty in specifying the transition from low to high angle of attack, we shall restrict the present consideration to the first case, the low angle of attack.

"Hayes' hypersonic approximation states that any plane slab of fluid initially perpendicular to the undisturbed flow may be assumed to remain so as it is swept downstream and to move in its own plane under the laws of one-dimensional, unsteady motion. Thus, the problem of a wing having an arbitrarily prescribed motion normal to its surface may be reduced to the consideration of the one-dimensional motion of a piston into an otherwise undisturbed flow. This problem is relatively simple if the disturbances produced by the piston are treated as simple waves, for then the pressure on the piston depends only on the instantaneous velocity there, w, and is given by

$$p/p_o = [1 + (1/2)(\gamma-1)(w/a_o)]^{2\gamma/(\gamma-1)} \qquad (1)$$

where p_o and a_o are the values of pressure and sonic velocity in the undisturbed flow.

"The result, Eq. (1), is exact for an expansion, but the presence of a shock front (and consequent departure from isentropic flow) renders it only approximate for a compression. Lighthill has suggested a cubic approximation

to be adequate for practical application if $|w/a_o| < 1$. The series expansion yields

$$p/p_o = 1 + \gamma(w/a_o) + (1/4)\,\gamma(\gamma + 1)\,(w/a_o)^2 + (1/12)\,\gamma(\gamma + 1)\,(w/a_o)^3 \quad . \tag{2}$$

Lighthill has shown that this expression, Eq. (2), is within six percent of the value given by either Eq. (1) or the exact solution with the shock at maximum permissible strength."[5]

The pressure coefficient $C_p = (p - p_o)/q$ is found from Eq. (2) after noting that $q = (\gamma/2)\,p_o M^2$.

$$C_p = (2/M^2)\,[\,(w/a_o) + (1/4)\,(\gamma + 1)\,(w/a_o)^2 + (1/12)\,(\gamma + 1)\,(w/a_o)^3\,] \tag{3}$$

Following a suggestion of Morgan, Huckel, and Runyan,[2] we may generalize this result, Eq. (3), by writing

$$C_p = (2/M^2)\,[\,C_1(w/a_o) + C_2(w/a_o)^2 + C_3(w/a_o)^3\,] \tag{4}$$

in which for piston theory

$$C_1 = 1, \qquad C_2 = (\gamma + 1)/4, \qquad C_3 = (\gamma + 1)/12 \tag{5}$$

and for the quasi-steady theory of Van Dyke[3]

$$C_1 = M/\beta, \qquad C_2 = [\,M^4(\gamma + 1) - 4\beta^2\,]/4\beta^4, \qquad C_3 = (\gamma + 1)/12 \tag{6}$$

Van Dyke gives only the second-order solution so that the value of C_3 is taken from the piston theory result. The use of the modified coefficients C_1 and C_2 could extend the lower Mach number limit of piston theory.

We may now calculate the lifting pressure coefficient from Eq. (4) and the local piston velocity. The normal velocity (positive away from the surface) on the upper and lower surfaces of a symmetrical thin airfoil having thickness distribution $2g(x)$ and angle of attack α_o is given by

$$w_u = V\,(g_x - \alpha_o - v) \quad , \tag{7a}$$

$$w_\ell = V\,(g_x + \alpha_o + v) \quad , \tag{7b}$$

where v is the unsteady component of the dimensionless downwash.

For the case of small angles of attack, the lifting pressure (positive down) is

$$C_p = C_{p_u} - C_{p_\ell} = -\,(4/M)\,[(C_1 + 2C_2Mg_x + 3C_3M^2g_x^2)(\alpha_o + v) + C_3M^2(\alpha_o + v)^3] \quad . \tag{8}$$

If, consistent with the small perturbation assumptions of aeroelastic analysis, only the terms linear in v are retained, Eq. (8) becomes

$$C_p = -\,(4v/M)\,[C_1 + 2C_2Mg_x + 3C_3M^2(g_x^2 + \alpha_o^2)] \quad . \tag{9}$$

Before discussing the swept wing transformation, it is appropriate to review the limitations of Eq. (9). Ashley and Zartarian[1] have shown that the piston theory is applicable if any of the conditions $M^2 >> 1$, $Mk >> 1$, or

$k^2 >> 1$ is met. We see that for low reduced frequency the Mach number necessarily must be high. However, if the reduced frequency is large the Mach number is not necessarily large; in fact it could be transonic or even subsonic. At this point it is apparent that any sweep correction introduced to bring piston theory into line with linearized supersonic theory must be considered as a low frequency approximation.

The result, Eq. (9), applies to the swept wing case if all quantities are determined by the flow characteristics normal to the leading edge. The expressions may be rewritten in the form

$$\overline{C}_p = -(4\overline{v}/\overline{M})\,[\,\overline{C}_1 + 2\overline{C}_2\overline{M}g_{\overline{x}} + 3C_3\overline{M}^2(\overline{g}_{\overline{x}}^2 + \overline{a}_o^2)\,] \qquad (10)$$

The transformation from the normal values to the free stream values are the following:

the Mach number

$$\overline{M} = M\cos\Lambda \quad ; \qquad (11a)$$

the geometry

$$\overline{x} = x\cos\Lambda \qquad (11b)$$

$$\overline{b} = b\cos\Lambda \quad ; \qquad (11c)$$

the angles of attack and slope

$$\overline{a}_o = a_o/\cos\Lambda \qquad (11d)$$

$$\overline{\beta} = \beta/\cos\Lambda \qquad (11e)$$

$$\overline{g}_{\overline{x}} = g_x/\cos\Lambda \quad ; \qquad (11f)$$

the dynamic pressure

$$\overline{q} = q\cos^2\Lambda \quad ; \qquad (11g)$$

and the pressure coefficient

$$C_p = \overline{C}_p \cos^2 \Lambda \quad . \tag{11h}$$

We note that h and k are invariant. From the dimensionless downwash

$$v = (1/V) \{ \dot{h} + V\alpha + (x - x_o)\dot{\alpha} + [V\beta + (x - x_h)\dot{\beta}] \ \underline{1}(x - x_h) \} \quad , \tag{12}$$

which for harmonic motion becomes

$$v = ikh/b + [1 + i(k/b) (x - x_o)] \alpha + [1 + i(k/b) (x - x_h)] \beta \ \underline{1}(x - x_h) \quad , \tag{13}$$

we find the transformed value

$$\overline{v} = ikh/\overline{b} + [1 + i(k/\overline{b}) (\overline{x} - \overline{x}_o)] \overline{\alpha} + [1 + i(k/\overline{b}) (\overline{x} - \overline{x}_h)] \overline{\beta} \ \underline{1}(\overline{x} - \overline{x}_h) \tag{14a}$$

$$= ikh/b \cos \Lambda + [1 + i(k/b) (x - x_o)] \alpha/\cos \Lambda + [1 + i(k/b) (x - x_h)] \ (\beta/\cos \Lambda) \ \underline{1}(x - x_h) \tag{14b}$$

$$= v/\cos \Lambda \tag{14c}$$

The transformed pressure coefficient becomes

$$C_p = \overline{C}_p \cos^2 \Lambda = [-4(v/\cos \Lambda) \cos^2 \Lambda / M \cos \Lambda]$$

$$\times [\overline{C}_1 + 2\overline{C}_2(M \cos \Lambda)(g_x/\cos \Lambda)$$

$$+ 3\overline{C}_3(M \cos \Lambda)^2 (g_x^2 + a_o^2)/\cos^2 \Lambda] \tag{15a}$$

$$= -(4v/M)[\overline{C}_1 + 2\overline{C}_2 M g_x + 3C_3 M^2(g_x^2 + a_o^2)] \quad . \tag{15b}$$

We note that the sweep effect shows up only in the coefficients $\overline{C}_1$ and $\overline{C}_2$; for piston theory, there is no effect

$$\overline{C}_1 = C_1 = 1, \quad \overline{C}_2 = C_2 = (\gamma + 1)/4 \quad , \tag{16}$$

and for the quasi-steady supersonic theory

$$\overline{C}_1 = M/(M^2 - \sec^2 \Lambda)^{1/2} \quad ,$$

$$\overline{C}_2 = [M^4(\gamma + 1) - 4 \sec^2 \Lambda (M^2 - \sec^2 \Lambda)]/[4(M^2 - \sec^2 \Lambda)^2 \quad . \tag{17}$$

Equation (17) is seen to be the most general result. If $\sec \Lambda$ is taken as zero then the piston theory results, Eqs. (16), are obtained; and if $\sec \Lambda$ is taken as unity the sweep correction is not made in the quasi-steady supersonic result.

We next consider the integration of the pressure coefficients obtained above. The oscillatory aerodynamic coefficients referred to the leading edge are defined by the following equations.

$$dL/dy = 4\rho\omega^2 b^3 \left(L_{h_o} h_o/b + L_{a_o} a + L_{\beta_o} \beta \right) \quad (18a)$$

$$dM/dy = 4\rho\omega^2 b^4 \left(M_{h_o} h_o/b + M_{a_o} a + M_{\beta_o} \beta \right) \quad (18b)$$

$$dT/dy = 4\rho\omega^2 b^4 \left(T_{h_o} h_o/b + T_{a_o} a + T_{\beta_o} \beta \right) \quad (18c)$$

The lift, moment, and hinge moment are found from the pressure coefficient

$$dL/dy = q \int_0^{2b} C_p \, dx \quad (19a)$$

$$dM/dy = q \int_0^{2b} x \, C_p \, dx \quad (19b)$$

$$dT/dy = q \int_0^{2b} (x - x_h) \, C_p \, dx \quad (19c)$$

where the pressure coefficient is given by Eq. (15b).

$$C_p = -(4/M) \left[\overline{C}_1 + 2\overline{C}_2 M g_x + 3C_3 M^2 (g_x^2 + a_o^2) \right] \times \left\{ ikh_o/b + [1 + ikx/b]\, a + [1 + ik(x - x_h)/b]\, \beta \, \underline{1}(x - x_h) \right\} \quad (20)$$

and we have taken the pitch axis at the leading edge $x_o = 0$. We define the following dimensionless thickness integrals

$$I_1 = (1/2b) \int_0^{2b} g_x \, dx \quad (21a)$$

$$I_2 = (1/4b^2) \int_0^{2b} x\, g_x\, dx \tag{21b}$$

$$I_3 = (1/8b^3) \int_0^{2b} x^2\, g_x\, dx \tag{21c}$$

$$I_4 = (1/2b) \int_0^{2b} g_x^2\, dx \tag{21d}$$

$$I_5 = (1/4b^2) \int_0^{2b} x\, g_x^2\, dx \tag{21e}$$

$$I_6 = (1/8b^3) \int_0^{2b} x^2 g_x^2\, dx \tag{21f}$$

$$J_1 = (1/2b) \int_{x_h}^{2b} g_x\, dx \tag{22a}$$

$$J_2 = (1/4b^2) \int_{x_h}^{2b} x\, g_x\, dx \tag{22b}$$

$$J_3 = (1/8b^3) \int_{x_h}^{2b} x^2\, g_x\, dx \tag{22c}$$

$$J_4 = (1/2b) \int_{x_h}^{2b} g_x^2\, dx \tag{22d}$$

$$J_5 = (1/4b^2) \int_{x_h}^{2b} x\, g_x^2\, dx \tag{22e}$$

$$J_6 = (1/8b^3) \int_{x_h}^{2b} x^2\, g_x^2\, dx \quad . \tag{22f}$$

These thickness integrals are evaluated at the end of this section for a typical airfoil. If we substitute Eq. (20) into Eqs. (19), make use of the definitions Eqs. (21) and (22) of the thickness integrals, and identify the resulting expressions with Eqs. (18), we obtain the oscillatory aerodynamic coefficients

$$L_{h_o} = - iK_1/k \tag{23a}$$

$$L_{\alpha_o} = - K_1/k^2 - iK_2/k \tag{23b}$$

$$L_{\beta_o} = - K_4/k^2 - i(K_5 - 2K_4\xi_h)/k \tag{23c}$$

$$M_{h_o} = - iK_2/k \tag{23d}$$

$$M_{\alpha_o} = - K_2/k^2 - iK_3/k \tag{23e}$$

$$M_{\beta_o} = - K_5/k^2 - i(K_6 - 2K_5\xi_h)/k \tag{23f}$$

$$T_{h_o} = - i\, (K_5 - 2K_4\, \xi_h)/k \tag{23g}$$

$$T_{\alpha_o} = -(K_5 - 2K_4\xi_h)/k^2 - i(K_6 - 2K_5\xi_h)/k \tag{23h}$$

$$T_{\beta_o} = -(K_5 - 2K_4\xi_h)/k^2 - i(K_6 - 4K_5\xi_h + 4K_4\xi_h^2)/k \tag{23i}$$

where

$$\xi_h = x_h/2b \tag{24a}$$

$$K_1 = (1/M)\,[\overline{C}_1 + 2\overline{C}_2 M I_1 + 3C_3 M^2 (I_4 + a_o^2)] \tag{24b}$$

$$K_2 = (1/M)\,[\overline{C}_1 + 4\overline{C}_2 M I_2 + 3C_3 M^2 (2I_5 + a_o^2)] \tag{24c}$$

$$K_3 = (4/3M)\,[\overline{C}_1 + 6\overline{C}_2 M I_3 + 3C_3 M^2 (3I_6 + a_o^2)] \tag{24d}$$

$$K_4 = (1/M)\left\{\overline{C}_1(1 - \xi_h) + 2\overline{C}_2 M J_1 + 3C_3 M^2 [J_4 + a_o^2(1 - \xi_h)]\right\} \tag{24e}$$

$$K_5 = (1/M)\left\{\overline{C}_1(1 - \xi_h^2) + 4\overline{C}_2 M J_2 + 3C_3 M^2 [2J_5 + a_o^2(1 - \xi_h^2)]\right\} \tag{24f}$$

$$K_6 = (4/3M)\left\{\overline{C}_1(1 - \xi_h^3) + 6\overline{C}_2 M J_3 + 3C_3 M^2 [3J_6 + a_o^2(1 - \xi_h^3)]\right\} \quad . \tag{24g}$$

To conclude the derivation of the oscillatory aerodynamic coefficients, we calculate the thickness integrals for the typical airfoil of Fig. 1. We approximate the airfoil by two parabolas and a line. The equation of the forward parabola that goes through the leading edge* and is horizontal at the point of the maximum thickness is

$$g_1(x)/c = (\tau/2)\,(x/x_m)\,(2 - x/x_m) \tag{25}$$

*The approximation by a sharp leading edge is consistent with the theory having ruled out detached shock waves.

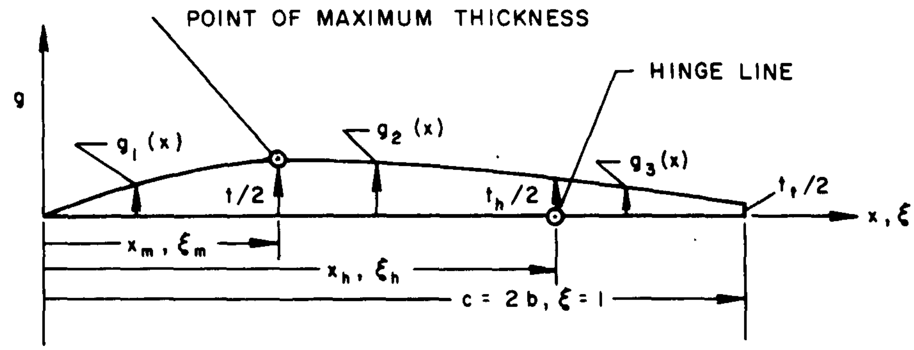


Fig. 1. Typical Airfoil Cross Section.

where $\tau = t_{max}/c$. The second parabola, horizontal at the point of maximum thickness and going through the hinge line, is

$$g_2(x)/c = (\tau/2)\left\{1 - (1 - r_h)\left[(x - x_m)/(x_h - x_m)\right]^2\right\} \tag{26}$$

where $r_h = \tau_h/\tau$ and $\tau_h = t_h/c$. The line connecting the hinge line and blunt trailing edge is given by

$$g_3(x)/c = (\tau_h/2)\left[1 - (1 - r_t)(x - x_h)/(c - x_h)\right] \tag{27}$$

where $r_t = \tau_t/\tau_h$ and $\tau_t = t_t/c$. By differentiating we find the desired slopes

$$g_1'(x)/c = (\tau/x_m)(1 - x/x_m) \tag{28a}$$

$$g_2'(x)/c = -\tau(1 - r_h)(x - x_m)/(x_h - x_m)^2 \tag{28b}$$

$$g_3'(x)/c = -(\tau_h/2)(1 - r_t)/(c - x_h) \quad . \tag{28c}$$

From the slopes, the thickness integrals follow immediately. Computing the control surface integrals first yields

$$J_1 = \int_{\xi_h}^{1} g_\xi d\xi = -(1/2)(\tau_h - \tau_t) \tag{29a}$$

$$J_2 = \int_{\xi_h}^{1} \xi g_\xi d\xi = -(1/4)(\tau_h - \tau_t)(1 + \xi_h) \tag{29b}$$

$$J_3 = \int_{\xi_h}^{1} \xi^2 g_\xi d\xi = -(1/6)(\tau_h - \tau_t)(1 + \xi_h + \xi_h^2) \tag{29c}$$

$$J_4 = \int_{\xi_h}^{1} g_\xi^2 d\xi = (1/4)(\tau_h - \tau_t)^2/(1 - \xi_h) \tag{29d}$$

$$J_5 = \int_{\xi_h}^{1} \xi g_\xi^2 d\xi = (1/8)(\tau_h - \tau_t)^2 (1 + \xi_h)/(1 - \xi_h) \tag{29e}$$

$$J_6 = \int_{\xi_h}^{1} \xi^2 g_\xi^2 d\xi = (1/12)(\tau_h - \tau_t)^2 (1 + \xi_h + \xi_h^2)/(1 - \xi_h) \quad : \tag{29f}$$

The complete airfoil integrals become

$$I_1 = \int_0^{\xi_h} g_\xi d\xi + J_1 = \tau_h/2 + J_1 \tag{30a}$$

$$I_2 = \int_0^{\xi_h} \xi g_\xi d\xi + J_2 = -(\tau/3)\xi_h + (\tau_h/6)(2\xi_h + \xi_m) + J_2 \tag{30b}$$

$$I_3 = \int_0^{\xi_h} \xi^2 g_\xi d\xi + J_3$$

$$= (\tau/12)\xi_m^2 - (1/12)(\tau - \tau_h)(3\xi_h^2 + 2\xi_h\xi_m + \xi_m^2) + J_3 \tag{30c}$$

$$I_4 = \int_0^{\xi_h} g_\xi^2 d\xi + J_4 = \tau^2/3\xi_m + (1/3)(\tau - \tau_h)^2/(\xi_h - \xi_m) + J_4 \tag{30d}$$

$$I_5 = \int_0^{\xi_h} \xi g_\xi^2 d\xi + J_5$$

$$= \tau^2/12 + (1/12)(\tau - \tau_h)^2 (3\xi_h + \xi_m)/(\xi_h - \xi_m) + J_5 \tag{30e}$$

$$I_6 = \int_0^{\xi_h} \xi^2 g_\xi^2 d\xi + J_6$$

$$= (\tau^2/30)\xi_m + (1/30)(\tau - \tau_h)^2 (6\xi_h^2 + 3\xi_h\xi_m + \xi_m^2)/(\xi_h - \xi_m) + J_6 \tag{30f}$$

where $\xi = x/c$, $\xi_m = x_m/c$, and $\xi_h = x_h/c$.

Having obtained the oscillatory aerodynamic coefficients, we are now in a position to derive the AICs. We consider the given and equivalent force systems in Fig. 2. The equivalent forces are arbitrarily placed at the quarter-chord, the control surface hinge line, and the trailing edge. The derivation must relate the forces F_1, F_2, F_3 to the deflections h_1, h_2, h_3 through the given leading edge aerodynamic coefficients and deflections h_o, α, β. We begin with the force equivalence.

$$\begin{bmatrix} 1 & 1 & 1 \\ b/2 & (b/2 + d) & 2b \\ 0 & 0 & c_a \end{bmatrix} \begin{Bmatrix} F_1 \\ F_2 \\ F_3 \end{Bmatrix} = \begin{Bmatrix} L_o \\ M_o \\ T_o \end{Bmatrix} \tag{31}$$

The loads and deflections are related through the definitions of the oscillatory coefficients.

$$\begin{Bmatrix} L_o \\ M_o \\ T_o \end{Bmatrix} = 4\rho\omega^2 b^2 \Delta y \begin{bmatrix} 1 & 0 & 0 \\ 0 & b & 0 \\ 0 & 0 & b \end{bmatrix} \begin{bmatrix} L_{h_o} & L_{\alpha_o} & L_{\beta_o} \\ M_{h_o} & M_{\alpha_o} & M_{\beta_o} \\ T_{h_o} & T_{\alpha_o} & T_{\beta_o} \end{bmatrix} \begin{Bmatrix} h_o \\ b\alpha \\ b\beta \end{Bmatrix} . \tag{32}$$

The equivalence in the deflections is given by

$$\begin{Bmatrix} h_o \\ b\alpha \\ b\beta \end{Bmatrix} = \begin{bmatrix} (1 + b/2d) & -b/2d & 0 \\ -b/d & b/d & 0 \\ b/d & -(b/d + b/c_a) & b/c_a \end{bmatrix} \begin{Bmatrix} h_1 \\ h_2 \\ h_3 \end{Bmatrix} . \tag{33}$$

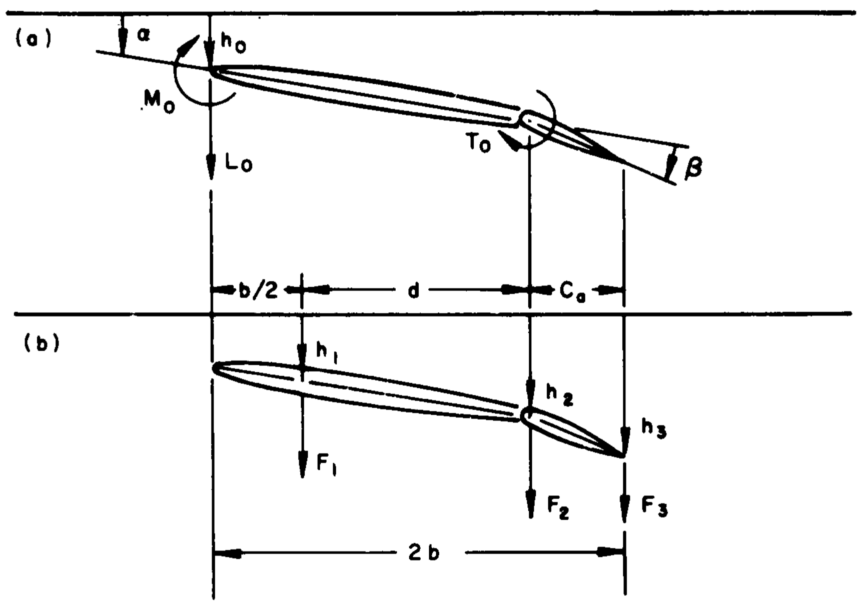


Fig. 2. Original (a) and Equivalent (b) Force Systems and Geometry for Oscillatory Case.

Substituting Eq. (33) into (32), Eq. (32) into (31), and solving for the forces yields

$$\begin{Bmatrix} F_1 \\ F_2 \\ F_3 \end{Bmatrix} = 4\rho\omega^2 b^2 \Delta y \begin{bmatrix} (1 + b/2d) & -b/d & (b/c_a)(3b/2d - 1) \\ -b/2d & b/d & -(b/c_a)(3b/2d) \\ 0 & 0 & b/c_a \end{bmatrix}$$

$$\times \begin{bmatrix} L_{h_o} & L_{\alpha_o} & L_{\beta_o} \\ M_{h_o} & M_{\alpha_o} & M_{\beta_o} \\ T_{h_o} & T_{\alpha_o} & T_{\beta_o} \end{bmatrix} \begin{bmatrix} (1 + b/2d) & -b/2d & 0 \\ -b/d & b/d & 0 \\ b/d & -(b/d + b/c_a) & b/c_a \end{bmatrix} . \quad (34)$$

From the definition of the AIC matrix

$$\{F\} = \rho\omega^2 b_r^2 s \, [C_h] \, \{h\} \quad , \quad (35)$$

and by identity with Eq. (34), we find the AICs for a single strip.

$$[C_h] = 4(b/b_r)^2(\Delta y/s) \begin{bmatrix} (1 + b/2d) & -b/d & (b/c_a)(3b/2d - 1) \\ -b/2d & b/d & -(b/c_a)(3b/2d) \\ 0 & 0 & b/c_a \end{bmatrix}$$

$$\times \begin{bmatrix} L_{h_o} & L_{\alpha_o} & L_{\beta_o} \\ M_{h_o} & M_{\alpha_o} & M_{\beta_o} \\ T_{h_o} & T_{\alpha_o} & T_{\beta_o} \end{bmatrix} \begin{bmatrix} (1 + b/2d) & -b/2d & 0 \\ -b/d & b/d & 0 \\ b/d & -(b/d + b/c_a) & b/c_a \end{bmatrix} . \quad (36)$$

In the absence of a control surface Eq.(36) reduces to

$$[C_h] = 4(b/b_r)^2 (\Delta y/s) \begin{bmatrix} (1 + b/2d) & -b/d \\ -b/2d & b/d \end{bmatrix}$$

$$\times \begin{bmatrix} L_{h_o} & L_{a_o} \\ M_{h_o} & M_{a_o} \end{bmatrix} \begin{bmatrix} (1 + b/2d) & -b/2d \\ -b/d & b/d \end{bmatrix} \quad . \tag{37}$$

The complete AIC matrix for a surface of N strips appears in the partitioned form

$$[C_h] = \left[\begin{array}{c|c|c|cccc|c} 0 & 0 & 0 & \cdot & \cdot & \cdot & \cdot & 0 \\ \hline 0 & C_{h1} & 0 & \cdot & \cdot & \cdot & \cdot & 0 \\ \hline 0 & 0 & C_{h2} & \cdot & \cdot & \cdot & \cdot & 0 \\ \hline \cdot & \cdot & \cdot & \cdot & & & & \cdot \\ \cdot & \cdot & \cdot & & \cdot & & & \cdot \\ \cdot & \cdot & \cdot & & & \cdot & & \cdot \\ \cdot & \cdot & \cdot & & & & \cdot & \cdot \\ \hline 0 & 0 & 0 & \cdot & \cdot & \cdot & \cdot & C_{hN} \end{array}\right] \tag{38}$$

in which the first null partition is reserved for control points at which the aerodynamic forces are negligible (e. g. , external stores) and in which the remaining partitions are of the size 3 x 3 or 2 x 2 according to whether or not the strip has a control surface.

The steady AIC matrix follows from the oscillatory solution as a limiting case. If we compare the definition of the steady matrix

$$\left|F\right| = (1/2)\rho\ V^2(S/\bar{c})\ [\,C_{hs}\,]\ \left|h\right| \tag{39}$$

with the oscillatory definition Eq. (35), we observe

$$[\,C_{hs}\,] = 2(s\bar{c}/S) \lim_{k_r \to 0} k_r^2 [\,C_h\,] \tag{40}$$

From the previous section we find the limiting values of the oscillatory coefficients to be

$$\lim_{k_r \to 0} \left(k_r^2 L_{h_o},\ k_r^2 M_{h_o},\ k_r^2 T_{h_o} \right) = 0 \tag{41}$$

$$\lim_{k_r \to 0} k_r^2 L_{\alpha_o} = -\ K_1 (b_r/b)^2 \tag{42a}$$

$$\lim_{k_r \to 0} k_r^2 M_{\alpha_o} = -\ K_2 (b_r/b)^2 \tag{42b}$$

$$\lim_{k_r \to 0} k_r^2 T_{\alpha_o} = -\ (K_5 - 2K_4 \xi_h)\,(b_r/b)^2 \tag{42c}$$

$$\lim_{k_r \to 0} k_r^2 L_{\beta_o} = -\ K_4 (b_r/b)^2 \tag{43a}$$

$$\lim_{k_r \to 0} k_r^2 M_{\beta_o} = - K_5 (b_r/b)^2 \tag{43b}$$

$$\lim_{k_r \to 0} k_r^2 T_{\beta_o} = - (K_5 - 2K_4 \xi_h) (b_r/b)^2 \tag{43c}$$

D. References

1. H. Ashley and G. Zartarian. "Piston Theory--A New Aerodynamic Tool for the Aeroelastician." Journal of the Aeronautical Sciences, 23 (1956), 1109.

2. H. G. Morgan, V. Huckel, and H. L. Runyan. "Procedure for Calculating Flutter at High Supersonic Speed Including Camber Deflections, and Comparison with Experimental Results." NACA TN 4335, September 1958.

3. M. D. Van Dyke. "A Study of Second-Order Supersonic Flow Theory." NACA Report 1081, 1952.

4. W. P. Rodden, E. F. Farkas, P. E. Williams, and F. C. Slack. "Aerodynamic Influence Coefficients ~~by~~ for Piston Theory: Analytical Development and Computational Procedure ~~for the IBM 7090 Computer~~." Northrop Corporation Report NOR-61-57, 14 April 1961.

5. J. W. Miles. The Potential Theory of Unsteady Supersonic Flow. London: Cambridge University Press, 1959, pp. 184-185.

SECTION II

GENERAL DESCRIPTION OF INPUT

A. Units

Since all dimensional input is geometrical and the aerodynamic matrix is dimensionless, only a consistent set of length units is necessary--inches or feet.

B. Classes of Numerical Data and Limitations

The data required by the program are control and option indicators, geometry, Mach numbers, and a set of reduced velocities for each Mach number. The example problem illustrates their use.

1. Example Problem

We consider the four-strip wing shown in Fig. 3 at Mach numbers 1.8 and 2.5. We use reduced velocities of 4.0 and 8.0 for both Mach numbers, and compute the steady case for Mach 2.5. The aerodynamic matrices will be computed by piston theory and by Van Dyke's quasi-steady variation. Strips 2 and 3 are considered to have control surfaces. The thickness integrals will be computed for an assumed airfoil (constant across the span) having 10 percent thickness, maximum thickness at 40 percent chord, and a blunt trailing edge having 1.5 percent thickness.

2. Program Restrictions and Options

a. The number of strips into which a wing may be subdivided must be ≤ 25.

b. The number of Mach numbers must be ≤ 15.

c. The number of reduced velocities used with any one Mach number must be ≤ 20.

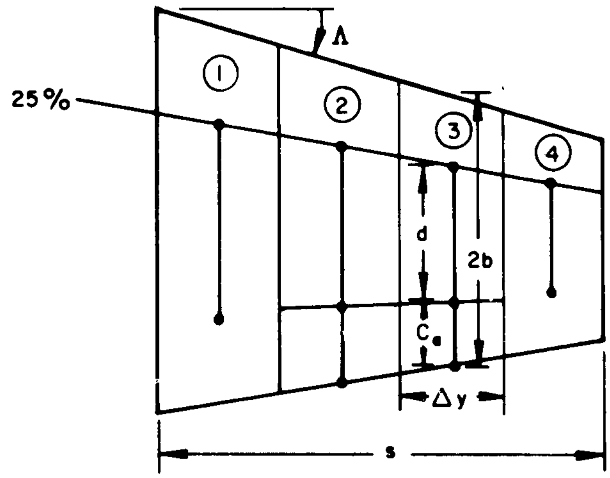


Fig. 3. Example of Four-Strip Wing.

Strip No.	Δy(ft)	b(ft)	c_a(ft)	d(ft)
1	4.7	12.28120	0	11.9
2	4.2	9.50000	5.25000	9.0
3	3.6	7.06250	3.99375	6.6
4	3.1	4.96875	0	4.5

Strip No.	ξ_m	ξ_h	τ	τ_h	τ_t
1	0.4	(not used)	0.1	0.015*	(not used)
2	0.4	0.72368421	0.1	0.050	0.015
3	0.4	0.71725664	0.1	0.050	0.015
4	0.4	(not used)	0.1	0.015*	(not used)

$\sec\Lambda = 1.25$ $S = 554.0$ sq ft

$b_r = 6.5$ ft $\bar{c} = 21.0$ ft

$s = 15.6$ ft a_o's (constant) $= 5.0^o$

*N. B. The trailing edge thickness is listed as the hinge line thickness in the case of no control surface.

d. If it is desired to compute the steady matrix $[C_{hs}]$, a zero or negative value of $V/b_r\omega$ must be supplied to the program. (S and $\bar{c}$ must also be provided.)

e. Thickness integrals may be given or computed. If given they may be given only once with each deck and are considered constant with strips. a_o's may be constant or vary with strips (for each Mach number). (τ, τ_h, τ_t)'s may be constant or vary with strips. ξ_m and ξ_h may be constant or vary with strips.

f. The control surface strips must be a continuation of the main surface strips; e.g., in the case of a partial span control surface the inboard and outboard span stations should be used as boundaries of the main surface strips.

g. As many complete sets (decks) of input data may be supplied as desired (one following the other).

SECTION III

DATA DECK SETUP

A. Loading Order

Input decks punched from keypunch forms are loaded behind column binary deck HM11. The data for each deck should be in the following order:

(1) Heading Card 1

(2) Heading Card 2

(3) NTHRY, NTHICK, NALPHA, NTAUS, NZETAS*

(4) ISZ, MSZ, NO PUNJ, JSZ_1, JSZ_2, . . . JSZ_{MSZ}

(5) $\sec \Lambda$, b_r, s, S, $\bar{c}$

(6) Δy_1, Δy_2, . . . , Δ_{ISZ}

(7) b_1, b_2, . . . , b_{ISZ}

(8) c_{a1}, c_{a2}, . . . , c_{aISZ}

(9) d_1, d_2, . . . , d_{ISZ}

(10) $Mach_1$, $Mach_2$, . . . , $Mach_{MSZ}$

(11a) If thickness integrals are given:

(a) When all $c_{ai} = 0$ tabulate only I_1, I_2, ... , I_6.

(b) Any $c_{ai} \neq 0$ then include J_1, J_2, ... , J_6, and ξ_{h1}, ξ_{h2}, . . . , ξ_{hISZ} (if NZETAS = 1 only ξ_{h1} is needed).

(11b) If thickness integrals are computed:

(a) τ_1, τ_{h1}, τ_{t1}; τ_2, τ_{h2}, τ_{t2}; . . ; . . ; τ_{ISZ}, τ_{hISZ}, τ_{tISZ} [if NTAUS = 1 only τ_1, τ_{h1}, and τ_{t1} are needed; if $c_{ai} = 0$ (i.e., no control surface), the trailing edge thickness (τ_{ti}) is listed as τ_{hi}, and the location for τ_{ti} may be left blank for these strips].

---

*Please, no remarks about our Greek!

(b) $\xi_{m1}, \xi_{h1}; \xi_{m2}, \xi_{h2}; \ldots; \xi_{mISZ}, \xi_{hISZ}$ [if NZETA = 1 only ξ_{m1} and ξ_{h1} are needed; if $c_{ai} = 0$, the program uses $\xi_h = 1.0$ (ξ for trailing edge), and the location for ξ_{hi} may be left blank for these strips].

(12a) If alphas do not vary with strips:

$\alpha_1, \alpha_2, \ldots, \alpha_{MSZ}$

(12b) If alphas vary with strips:

(a) $\alpha_1, \alpha_2, \ldots, \alpha_{ISZ}$ for first Mach number

(b) $\alpha_1, \alpha_2, \ldots, \alpha_{ISZ}$ for second Mach number

(c) $\alpha_1, \alpha_2, \ldots, \alpha_{ISZ}$ for MSZ Mach number

(13) $V/b_r\omega$ series

(a) $(V/b_r\omega)_1, (V/b_r\omega)_2, \ldots, (V/b_r\omega)_{JSZ}$ for first Mach number

(b) $(V/b_r\omega)_1, (V/b_r\omega)_2, \ldots, (V/b_r\omega)_{JSZ}$ for second Mach number

(c) $(V/b_r\omega)_1, (V/b_r\omega)_2, \ldots, (V/b_r\omega)_{JSZ}$ for MSZ Mach number

B. <u>Input Data Description</u>

(1), (2) Heading Card 1 and Heading Card 2 may contain any characters desired in Columns 2 through 72. These cards are convenient for identifying the vehicle, surface, date, engineer, etc. Both cards may be blank but must be included in the data deck.

(3) Control card: FORMAT (18I4)

(a) NTHRY = 0, piston theory is used to compute $\mathcal{C}_1$ and $\mathcal{C}_2$

NTHRY $\neq$ 0, Van Dyke's theory is used to compute $\overline{C}_1$ and $\overline{C}_2$ (If sec Λ = 0, then with either theory $\overline{C}_1$ and $\overline{C}_2$ are the same)

(b) NTHICK = 0, when thickness integrals are computed

NTHICK $\neq$ 0, when thickness integrals are given (in this case they are constant for the surface)

(c) NALPHA = 1, the alphas are constant (do not vary with each strip)

NALPHA = ISZ, the alphas vary with each strip

(d) NTAUS = 1, the τ, τ_h, and τ_t are constant for all strips

NTAUS = ISZ, the τ, τ_h, and τ_t vary with each strip

(e) NZETAS = 1, ξ_m and ξ_h are constant for all strips

NZETAS = ISZ, ξ_m and ξ_h vary with each strip

(4) Control card: FORMAT (18I4)

(a) ISZ = number of strips, ≤ 25

(b) MSZ = number of Mach numbers, ≤ 15

(c) NO PUNJ = 0, or blank, when punched card output is desired

NO PUNJ $\neq$ 0, no punched output is desired

(d) JSZ_1 = number of $(V/b_r\omega)$'s for first Mach number, ≤ 20

JSZ_2 = number of $(V/b_r\omega)$'s for second Mach number, ≤ 20

.
.
.

JSZ_{MSZ} = number of $(V/b_r\omega)$'s for last Mach number, ≤ 20

(5) Single parameters: FORMAT (6E12.8)

(a) sec Λ, secant of leading edge sweep angle

(b) b_r, reference semichord

(c) s, wing semispan

(d) S, wing area

(e) $\bar{c}$, mean aerodynamic chord

(6) Δy_i series: FORMAT (6E12.8)

$\Delta y_1 \ldots \Delta y_{ISZ}$, strip widths

(7) b_i series: FORMAT (6E12.8)

$b_1 \ldots b_{ISZ}$, local semichords

(8) c_{ai} series: FORMAT (6E12.8)

$c_{a1} \ldots c_{aISZ}$, control surface chords; in the absence of a control surface, c_{ai} may be zero or blank, but a sufficient number of cards must be included

(9) d_i series: FORMAT (6E12.8)

$d_1 \ldots d_{ISZ}$, distance between forward and aft control points

(10) Mach number series: FORMAT (6E12.8)

$\text{Mach}_1 \ldots \text{Mach}_{MSZ}$, in any order desired, but the number listed must agree with MSZ

(11a) Thickness integrals given: FORMAT (6E12.8)

(a) $I_1, I_2, \ldots, I_6$, the complete airfoil thickness integrals

(b) $J_1, J_2, \ldots, J_6$, the control surface thickness integrals, use only when $c_{ai} \neq 0$

$\xi_{h1}, \xi_{h2}, \ldots, \xi_{hISZ}$, dimensionless chordwise coordinate (x_h/c) for the control surface hinge line

(11b) Thickness integrals are computed: FORMAT (6E12.8)

(a) τ_i, τ_{hi}, and τ_{ti}, airfoil thickness ratios (t/c) at point of maximum thickness, hinge line, and trailing edge, respectively

(b) ξ_{mi} and ξ_{hi}, dimensionless chordwise coordinates for point of maximum thickness and hinge line

(12a) Alphas do not vary with strips (alpha is α_o, the initial angle of attack). FORMAT (6E12.8)

α_1, α_2 . . α_{MSZ} (degrees) are tabulated in order for each Mach number

(12b) Alphas vary with strips: FORMAT (6E12.8)

α_1, α_2, . . . , α_{ISZ} (degrees) are tabulated for each Mach number. The series for each Mach number starts on a new line (card).

(13) $V/b_r\omega$ series, reference reduced velocity: FORMAT (6E12.8)

There is a reduced velocity series for each Mach number; each series starts on a new line (card), and the number of $V/b_r\omega$'s must agree with the JSZ for the respective Mach number.

C. <u>Example Keypunch Forms</u>

Example keypunch forms are given on the following pages. Columns 73 through 80 are reserved for data deck identification. This space may be used in any fashion; however, it is suggested that the last three columns be used for sequencing. Only the cards with sequencing in Columns 73 through 80 are to be used in the sample data deck; the lines (cards) with Columns 73 through 80 blank are for clarification of input.

```
 EXAMPLE PRØBLEM HEADING                                                HM110001
 BLØØPER JET  JAN.25, 1960  P.E. WILLIAMS                               HM110002
   0   0   1   4   4                                                    HM110003
   4   2   0   2   3                                                    HM110004
```

Heading Card 1

Heading Card 2

NZETAS

NTAUS

NALPHA

NTHICK

NTHRY

JSZ--for second Mach number

JSZ--for first Mach number

NO PUNJ

MSZ

ISZ

sec Λ	b_r	s	S	$\bar{c}$		
1.25	6.5	15.6	554.0	21.0		HM110005
Δy_1	Δy_2	Δy_3	Δy_4	Δy_5	Δy_6	
4.7	4.2	3.6	3.1			HM110006
b_1	b_2	b_3	b_4	b_5	b_6	
12.28112	9.5	7.0625	496875 +01			HM110007
ca_1	ca_2	ca_3	ca_4	ca_5	ca_6	
0	5.25	3.99375	0			HM110008
d_1	d_2	d_3	d_4	d_5	d_6	
11.9	9.	6.6	4.5			HM110009
$Mach_1$	$Mach_2$	$Mach_3$	$Mach_4$	$Mach_5$	$Mach_6$	
1.8	2.5					HM110010
τ_1	τ_{h1}	τ_{t1}	τ_2	τ_{h2}	τ_{t2}	
.1	.015		.1	.05	.015	HM110011
τ_3	τ_{h3}	τ_{t3}	τ_4	τ_{h4}	τ_{t4}	
.1	.05	.015	.1	.015	0	HM110012
ξ_{m1}	ξ_{h1}	ξ_{m2}	ξ_{h2}	ξ_{m3}	ξ_{h3}	
.4		.4	72368421	.4	71725664	HM110013

$\xi m4$	$\xi h4$	$\xi m5$	$\xi h5$	$\xi m6$	$\xi h6$	
.4	0					HM110014
a_1	a_2	a_3	a_4	a_5	a_6	
5.	5.					HM110015
$(V/b_r\omega)1$	$(V/b_r\omega)2$	(for first Mach number)				
4.0	8.0					HM110016
$(V/b_r\omega)1$	$(V/b_r\omega)2$	(for second Mach number)				
4.0	8.0	0				HM110017

NOTE: EACH NEW SERIES STARTS ON A NEW LINE (CARD): FORMAT (6E12.8)

The second case is identical except for the following card (Van Dyke's quasi-steady correction is used).

1 0 1	4 4					HM110003

SECTION IV

PROGRAM OUTPUT

A. <u>Printed Output</u>

1. All input data
2. Thickness integrals (I's and J's)
3. Each group of aerodynamics influence coefficients (comprising a complete aerodynamic matrix), associated Mach number, and $V/b_r\omega$
4. Sequencing numbers (Columns 73 through 80) of the first and last punched cards (output) for each group (one $V/b_r\omega$) of influence coefficients
5. Example problem printed output is shown on the following pages

AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY

INPUT DATA

4 STRIPS
2 MACH NUMBERS
5 REDUCED FREQUENCIES (TOTAL)

SECANT LAMBDA = 0.12499999E 01
BR = 0.64999999E 01
S = 0.15600000E 02
$ = 0.55400000E 03
C BAR = 0.20999999E 02

STRIP	DELTA Y (I)	B(I)	CA(I)	D(I)
1	0.46999999E 01	0.12281200E 02	0.	0.11900000E 02
2	0.41999999E 01	0.95000000E 01	0.52499999E 01	0.89999999E 01
3	0.35999999E 01	0.70625000E 01	0.39937499E 01	0.65999999E 01
4	0.30999999E 01	0.49687500E 01	0.	0.45000000E 01

STRIP	XI M	XI H	TAU	TAU H	TAU T
1	0.40000000E-00	0.09999999E 01	0.09999999E-00	0.15000000E-01	0.
2	0.40000000E-00	0.72368421E 00	0.09999999E-00	0.49999999E-01	0.15000000E-01
3	0.40000000E-00	0.71725664E 00	0.09999999E-00	0.49999999E-01	0.15000000E-01
4	0.40000000E-00	0.09999999E 01	0.09999999E-00	0.15000000E-01	0.

MACH NUMBER = 1.80000000
1/K(R) = 0.40000000E 01
1/K(R) = 0.80000000E 01
ALPHA ZERO SERIES (DEGREES) = 5.00 5.00 5.00 5.00

MACH NUMBER = 2.50000000
1/K(R) = 0.40000000E 01
1/K(R) = 0.80000000E 01
1/K(R) = 0.
ALPHA ZERO SERIES (DEGREES) = 5.00 5.00 5.00 5.00

COMPUTED THICKNESS INTEGRALS

STRIP	J(1)	J(2)	J(3)	J(4)	J(5)	J(6)
1	0.	0.	0.	0.	0.	0.
2	-0.17500000E-01	-0.15082236E-01	-0.13109850E-01	0.11083332E-02	0.95520827E-03	0.83029052E-03
3	-0.17500000E-01	-0.15025999E-01	-0.13018329E-01	0.10831376E-02	0.93001267E-03	0.80575106E-03
4	0.	0.	0.	0.	0.	0.

STRIP	I(1)	I(2)	I(3)	I(4)	I(5)	I(6)
1	0.74999999E-02	-0.27333333E-01	-0.26716666E-01	0.97783331E-02	0.42451386E-02	0.30875553E-02
2	0.75000000E-02	-0.23810306E-01	-0.21401949E-01	0.97114031E-02	0.34433518E-02	0.20373899E-02
3	0.75000000E-02	-0.23646939E-01	-0.21173231E-01	0.96808512E-02	0.34390200E-02	0.20179822E-02
4	0.74999999E-02	-0.27333333E-01	-0.26716666E-01	0.97783331E-02	0.42451386E-02	0.30875553E-02

```
                    AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY        3

                                   OSCILLATORY CASE

                                 MACH =      1.80000000

                               1/K(R) =  0.40000000E 01

                                        4STRIPS

                                  CH(1) SIZE = 2 BY 2
          0.71788753E 01 -0.39289374E 01I -0.71788753E 01  0.64322150E 00I
          0.44294456E 01  0.64322149E 00I -0.44294456E 01 -0.26705447E 01I

                                  CH(2) SIZE = 3 BY 3
 0.70593633E 01 -0.26495353E 01I -0.70593633E 01  0.20590959E-00I -0.46521193E-07  0.19383830E-08I
 0.10759644E 01  0.20590963E-00I  0.10439030E 01 -0.86372529E 00I -0.21198674E 01 -0.14268377E-00I
-0.             -0.             I  0.21198682E 01 -0.14268376E-00I -0.21198682E 01 -0.28536656E-00I

                                  CH(3) SIZE = 3 BY 3
 0.61164010E 01 -0.16911002E 01I -0.61164010E 01  0.13847534E-00I -0.57432242E-07  0.89737879E-08I
 0.89529782E 00  0.13847534E-00I  0.92739177E 00 -0.55239360E 00I -0.18226895E 01 -0.93325315E-01I
-0.              0.15223674E-07I  0.18226899E 01 -0.93325322E-01I -0.18226900E 01 -0.18665039E-00I

                                  CH(4) SIZE = 2 BY 2
          0.48474802E 01 -0.10759194E 01I -0.48474802E 01  0.23693249E-00I
          0.33442195E 01  0.23693250E-00I -0.33442195E 01 -0.81573974E 00I

                        PUNCHED CARDS NOS. HM11    0 THRU HM11  12
```

```
                    AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY

                                  OSCILLATORY CASE

                                MACH =      1.80000000

                               1/K(R) =  0.80000000E 01

                                      4STRIPS

                                 CH(1) SIZE = 2 BY 2
         0.28715501E 02 -0.78578748E 01I -0.28715501E 02  0.12864430E 01I
         0.17717782E 02  0.12864430E 01I -0.17717782E 02 -0.53410894E 01I

                                 CH(2) SIZE = 3 BY 3
 0.28237453E 02 -0.52990707E 01I -0.28237453E 02  0.41181920E-00I -0.18608477E-06  0.38767660E-08I
 0.43038578E 01  0.41181927E-00I  0.41756120E 01 -0.17274506E 01I -0.84794699E 01 -0.28536754E-00I
-0.              -0.             I  0.84794731E 01 -0.28536753E-00I -0.84794731E 01 -0.57073312E 00I

                                 CH(3) SIZE = 3 BY 3
 0.24465604E 02 -0.33822004E 01I -0.24465603E 02  0.27695068E-00I -0.22972897E-06  0.17947575E-07I
 0.35811912E 01  0.27695069E-00I  0.37095670E 01 -0.11047871E 01I -0.72907583E 01 -0.18665063E-00I
-0.               0.30447347E-07I  0.72907599E 01 -0.18665064E-00I -0.72907600E 01 -0.37330078E-00I

                                 CH(4) SIZE = 2 BY 2
         0.19389921E 02 -0.21518388E 01I -0.19389921E 02  0.47386498E-00I
         0.13376877E 02  0.47386500E-00I -0.13376877E 02 -0.16314794E 01I

                         PUNCHED CARDS NOS. HM11  13 THRU HM11  25
```

AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY 5

OSCILLATORY CASE

MACH = 2.50000000

1/K(R) = 0.40000000E 01

4STRIPS

```
                              CH(1) SIZE = 2 BY 2
           0.57621686E 01 -0.31458882E 01I -0.57621686E 01  0.50858803E 00I
           0.28960149E 01  0.50858802E 00I -0.28960149E 01 -0.18340717E 01I

                              CH(2) SIZE = 3 BY 3
 0.55877510E 01 -0.21343287E 01I -0.55877510E 01  0.20010731E-00I  0.38767660E-07  0.58151491E-08I
 0.60791197E 00  0.20010730E-00I  0.86290549E 00 -0.60853299E 00I -0.14708174E 01 -0.98997385E-01I
-0.              0.21424233E-08I  0.14708177E 01 -0.98997386E-01I -0.14708177E 01 -0.19799466E-00I

                              CH(3) SIZE = 3 BY 3
 0.48428045E 01 -0.13624670E 01I -0.48428044E 01  0.13313967E-00I -0.15793866E-06 -0.17947575E-08I
 0.40889528E-00  0.13313968E-00I  0.76718581E 00 -0.38943376E-00I -0.12660810E 01 -0.64825930E-01I
-0.             -0.30447347E-08I  0.12660816E 01 -0.64825933E-01I -0.12660816E 01 -0.12965150E-00I

                              CH(4) SIZE = 2 BY 2
           0.39233785E 01 -0.86084867E 00I -0.39233785E 01  0.18180238E-00I
           0.21864834E 01  0.18180237E-00I -0.21864834E 01 -0.56023222E 00I
```

PUNCHED CARDS NOS. HM11 26 THRU HM11 38

```
AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY

OSCILLATORY CASE

MACH =      2.50000000

1/K(R) =  0.80000000E 01

4STRIPS

CH(1) SIZE = 2 BY 2
0.23048674E 02 -0.62917764E 01I -0.23048674E 02  0.10171760E 01I
0.11584059E 02  0.10171760E 01I -0.11584059E 02 -0.36681435E 01I

CH(2) SIZE = 3 BY 3
 0.22351003E 02 -0.42686575E 01I -0.22351003E 02  0.40021462E-00I  0.15507064E-06  0.11630298E-07I
 0.24316479E 01  0.40021461E-00I  0.34516219E 01 -0.12170660E 01I -0.58832698E 01 -0.19799477E-00I
-0.              0.42848467E-08I  0.58832709E 01 -0.19799477E-00I -0.58832709E 01 -0.39598934E-00I

CH(3) SIZE = 3 BY 3
 0.19371218E 02 -0.27249340E 01I -0.19371217E 02  0.26627934E-00I -0.63175466E-06 -0.35895152E-08I
 0.19956811E 01  0.26627935E-00I  0.30687432E 01 -0.77886754E 00I -0.50643244E 01 -0.12965186E-00I
-0.             -0.60894696E-08I  0.50643262E 01 -0.12965187E-00I -0.50643263E 01 -0.25930300E-00I

CH(4) SIZE = 2 BY 2
0.15693514E 02 -0.17216973E 01I -0.15693514E 02  0.36360475E-00I
0.87459339E 01  0.36360475E-00I -0.87459339E 01 -0.11204644E 01I

PUNCHED CARDS NOS. HM11  39 THRU HM11  51
```

7

AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY

STEADY CASE

MACH = 2.50000000

1/K(R) = INFINITY

4STRIPS

CH(1) SIZE = 2 BY 2

0.42592202E-00	-0.42592202E-00
0.21406464E-00	-0.21406464E-00

CH(2) SIZE = 3 BY 3

0.41302960E-00	-0.41302960E-00	0.28655878E-08
0.44935007E-01	0.63783355E-01	-0.10871836E-00
-0.	0.10871838E-00	-0.10871838E-00

CH(3) SIZE = 3 BY 3

0.35796542E-00	-0.35796541E-00	-0.11674347E-07
0.36876824E-01	0.56708048E-01	-0.93584874E-01
-0.	0.93584908E-01	-0.93584909E-01

CH(4) SIZE = 2 BY 2

0.29000423E-00	-0.29000423E-00
0.16161823E-00	-0.16161823E-00

PUNCHED CARDS NOS. HM11 52 THRU HM11 59

HM110686

HM110687

AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY
(WITH VAN DYKES QUASI-STEADY THEORY FINAGLING FACTOR)

INPUT DATA

4 STRIPS
2 MACH NUMBERS
5 REDUCED FREQUENCIES (TOTAL)

SECANT LAMBDA = 0.12499999E 01
BR = 0.64999999E 01
S = 0.15600000E 02
$ = 0.55400000E 03
C BAR = 0.20999999E 02

STRIP	DELTA Y (I)	B(I)	CA(I)	D(I)
1	0.46999999E 01	0.12281200E 02	-0.	0.11900000E 02
2	0.41999999E 01	0.95000000E 01	0.52499999E 01	0.89999999E 01
3	0.35999999E 01	0.70625000E 01	0.39937499E 01	0.65999999E 01
4	0.30999999E 01	0.49687500E 01	-0.	0.45000000E 01

STRIP	XI M	XI H	TAU	TAU H	TAU T
1	0.40000000E-00	0.09999999E 01	0.09999999E-00	0.15000000E-01	0.
2	0.40000000E-00	0.72368421E 00	0.09999999E-00	0.49999999E-01	0.15000000E-01
3	0.40000000E-C0	0.71725664E 00	0.09999999E-00	0.49999999E-01	0.15000000E-01
4	0.4C000000E-0C	0.09999999E 01	0.09999999E-00	0.15000000E-01	0.

MACH NUMBER = 1.80000000
1/K(R) = 0.40000000E 01
1/K(R) = 0.80000000E 01
ALPHA ZERO SERIES (DEGREES) = 5.00 5.00 5.00 5.00

MACH NUMBER = 2.50000000

1/K(R) = 0.40000000E 01
1/K(R) = 0.8C000000E 01 9
1/K(R) = -0.

ALPHA ZERO SERIES (DEGREES) = 5.00 5.00 5.00 5.00

COMPUTED THICKNESS INTEGRALS

STRIP	J(1)	J(2)	J(3)	J(4)	J(5)	J(6)
1	0.	0.	0.	0.	0.	0.
2	-0.17500000E-01	-0.15082236E-01	-0.13109850E-01	0.11083332E-02	0.95520827E-03	0.83029052E-03
3	-0.175000C0E-01	-0.15025995E-01	-0.13018329E-01	0.10831376E-02	0.93001267E-03	0.80575106E-03
4	0.	0.	0.	0.	0.	0.

STRIP	I(1)	I(2)	I(3)	I(4)	I(5)	I(6)
1	0.74999999E-02	-0.27333333E-01	-0.26716666E-01	0.97783331E-02	0.42451386E-02	0.30875553E-02
2	0.75000000E-02	-0.23813306E-01	-0.21401949E-01	0.97114031E-02	0.34433518E-02	0.20373899E-02
3	0.75C00000E-02	-0.23646939E-01	-0.21173231E-01	0.96808512E-02	0.34390200E-02	0.20179822E-02
4	0.74999999E-02	-0.27333333E-01	-0.26716666E-01	0.97783331E-02	0.42451386E-02	0.30875553E-02

```
AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY
 (WITH VAN DYKES QUASI-STEADY THEORY  FINAGLING FACTOR)

                 OSCILLATORY CASE

          MACH =       1.80000000

          1/K(R) =  0.40000000E 01

                   4STRIPS

                        CH(1) SIZE = 2 BY 2
           0.11171371E 02 -0.60500227E 01I -0.11171371E 02  0.93697202E 00I
           0.49569440E 01  0.93697204E 00I -0.49569440E 01 -0.32057271E 01I

                        CH(2) SIZE = 3 BY 3
 0.10692380E 02 -0.41086720E 01I -0.10692380E 02  0.40746380E-00I -0.77535321E-07 -0.23260596E-07I
 0.93588296E 00  0.40746372E-00I  0.17310714E 01 -0.10904364E 01I -0.26669544E 01 -0.17950657E-00I
-0.             -0.32136350E-07I  0.26669553E 01 -0.17950655E-00I -0.26669554E 01 -0.35901324E-00I

                        CH(3) SIZE = 3 BY 3
 0.92699547E 01 -0.26240122E 01I -0.92699547E 01  0.27086976E-00I -0.14358060E-07  0.53842727E-08I
 0.75487661E 00  0.27086976E-00I  0.15442599E 01 -0.69793279E 00I -0.22991365E 01 -0.11772014E-00I
-0.              0.81192928E-08I  0.22991367E 01 -0.11772015E-00I -0.22991368E 01 -0.23544054E-00I

                        CH(4) SIZE = 2 BY 2
           0.76388664E 01 -0.16535902E 01I -0.76388664E 01  0.33147874E-00I
           0.37424795E 01  0.33147871E-00I -0.37424795E 01 -0.97921555E 00I

             PUNCHED CARDS NOS. HM11  60 THRU HM11  72
```

```
                                      AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY
                                       (WITH VAN DYKES QUASI-STEADY THEORY  FINAGLING FACTOR)

                                                       OSCILLATORY CASE

                                                 MACH =        1.80000000

                                                 1/K(R) =  0.80000000E 01

                                                           4STRIPS

                                                  CH(1) SIZE = 2 BY 2
               0.44685484E 02 -0.12100045E 02I -0.44685484E 02  0.18739440E 01I
               0.19827776E 02  0.18739440E 01I -0.19827776E 02 -0.64114542E 01I

                                                  CH(2) SIZE = 3 BY 3
  0.42769518E 02 -0.82173441E 01I -0.42769518E 02  0.81492759E 00I -0.31014128E-06 -0.46521193E-07I
  0.37435318E 01  0.81492744E 00I  0.69242857E 01 -0.21808727E 01I -0.10667817E 02 -0.35901315E-00I
 -0.              -0.64272700E-07I  0.10667821E 02 -0.35901310E-00I -0.10667821E 02 -0.71802649E 00I

                                                  CH(3) SIZE = 3 BY 3
  0.37078819E 02 -0.52480243E 01I -0.37078819E 02  0.54173952E 00I -0.57432242E-07  0.10768545E-07I
  0.30198064E 01  0.54173952E 00I  0.61770397E 01 -0.13958655E 01I -0.91965462E 01 -0.23544029E-00I
 -0.               0.16238585E-07I  0.91965472E 01 -0.23544030E-00I -0.91965473E 01 -0.47088108E-00I

                                                  CH(4) SIZE = 2 BY 2
               0.30555465E 02 -0.33071805E 01I -0.30555465E 02  0.66295747E 00I
               0.14969917E 02  0.66295743E 00I -0.14969917E 02 -0.19584311E 01I

                                         PUNCHED CARDS NOS. HM11  73 THRU HM11  85
```

12

```
AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY
 (WITH VAN DYKES QUASI-STEADY THEORY  FINAGLING FACTOR)

                     OSCILLATORY CASE

                  MACH =       2.50000000

                1/K(R) =  0.40000000E 01

                          4STRIPS

                   CH(1) SIZE = 2 BY 2
 0.67178680E 01 -0.36588867E 01I -0.67178680E 01  0.58417013E 00I
 0.32115138E 01  0.58417010E 00I -0.32115138E 01 -0.20540553E 01I

                   CH(2) SIZE = 3 BY 3
 0.64845489E 01 -0.24841341E 01I -0.64845489E 01  0.23948260E-00I -0.38767660E-07  0.58151491E-08I
 0.64685941E 00  0.23948264E-00I  0.10177666E 01 -0.68747969E 00I -0.16646261E 01 -0.11204223E-00I
-0.             -0.             I  0.16646264E 01 -0.11204222E-00I -0.16646265E 01 -0.22408430E-00I

                   CH(3) SIZE = 3 BY 3
 0.56206739E 01 -0.15859851E 01I -0.56206737E 01  0.15919863E-00I -0.12922254E-06  0.17947575E-08I
 0.62784043E 00  0.15919863E-00I  0.90578000E 00 -0.43999702E-00I -0.14336204E 01 -0.73404239E-01I
-0.              0.40596464E-08I  0.14336210E 01 -0.73404244E-01I -0.14336210E 01 -0.14680822E-00I

                   CH(4) SIZE = 2 BY 2
 0.45822304E 01 -0.10008494E 01I -0.45822304E 01  0.20777106E-00I
 0.24246843E 01  0.20777106E-00I -0.24246843E 01 -0.62742798E 00I

         PUNCHED CARDS NOS. HM11  86 THRU HM11  98
```

13

```
             AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY
             (WITH VAN DYKES QUASI-STEADY THEORY  FINAGLING FACTOR)

                             OSCILLATORY CASE

                          MACH =       2.50000000

                        1/K(R) =  0.80000000E 01

                                 4STRIPS

                           CH(1) SIZE = 2 BY 2
       0.26871472E 02 -0.73177734E 01I -0.26871472E 02  0.11683402E 01I
       0.12846056E 02  0.11683401E 01I -0.12846056E 02 -0.41081105E 01I

                           CH(2) SIZE = 3 BY 3
 0.25938195E 02 -0.49682683E 01I -0.25938195E 02  0.47896520E-00I -0.15507064E-06  0.11630298E-07I
 0.25874376E 01  0.47896529E-00I  0.40710666E 01 -0.13749593E 01I -0.66585043E 01 -0.22408446E-00I
-0.           -0.               I  0.66585060E 01 -0.22408444E-00I -0.66585062E 01 -0.44816859E-00I

                           CH(3) SIZE = 3 BY 3
 0.22482695E 02 -0.31719703E 01I -0.22482695E 02  0.31839728E-00I -0.51689018E-06  0.35895152E-08I
 0.21113617E 01  0.31839726E-00I  0.36231200E 01 -0.87999405E 00I -0.57344817E 01 -0.14680848E-00I
-0.               0.81192928E-08I  0.57344840E 01 -0.14680848E-00I -0.57344840E 01 -0.29361644E-00I

                           CH(4) SIZE = 2 BY 2
       0.18328921E 02 -0.20016988E 01I -0.18328921E 02  0.41554212E-00I
       0.96987373E 01  0.41554213E-00I -0.96987373E 01 -0.12548559E 01I

                PUNCHED CARDS NOS. HM11  99 THRU HM11 111
```

14

AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY
(WITH VAN DYKES QUASI-STEADY THEORY FINAGLING FACTOR)

STEADY CASE

MACH = 2.50000000

1/K(R) = INFINITY

4STRIPS

CH(1) SIZE = 2 BY 2

0.49656443E-00	-0.49656443E-00
0.23738536E-00	-0.23738536E-00

CH(2) SIZE = 3 BY 3

0.47931818E-00	-0.47931818E-00	-0.28655878E-08
0.47813884E-01	0.75230224E-01	-0.12304410E-00
-0.	0.12304414E-00	-0.12304414E-00

CH(3) SIZE = 3 BY 3

0.41546316E-00	-0.41546316E-00	-0.95517385E-08
0.39016362E-01	0.66952509E-01	-0.10596887E-00
-0.	0.10596891E-00	-0.10596891E-00

CH(4) SIZE = 2 BY 2

0.33870457E-00	-0.33870457E-00
0.17922531E-00	-0.17922531E-00

PUNCHED CARDS NOS. HM11 112 THRU HM11 119

B. Punched Output

1. A deck of punched cards (output) from this program is suitable as an input deck to other programs requiring the use of AICs.

2. All punched output is sequenced in order on Columns 73 through 80 starting with HM110000. The data is punched in the following order:

   a. Card 1 contains $(V/b_r\omega)_1$ and M_1: FORMAT (6E12. 8)

   b. Card 2 contains the size (number of control points) of the AIC matrix and the number of strips: FORMAT (18I4)

   c. The AIC matrix punched in column binary form and its TRA card make up the remainder of the punched output for $(V/b_r\omega)_1$

3. The order of Statement 2 above is repeated for all reduced velocities and associated Mach numbers per input deck.

4. Each AIC matrix is punched by columns. Column 1 starts in Origin 1 and Column 2 in Location (1 + matrix size).

5. The oscillatory AIC matrix is punched in the order -- Column 1 (real), Column 1 (imaginary), Column 2 (real), Column 2 (imaginary), . . . , Column N (real), Column N (imaginary). In the steady case all columns are real and are punched in order.

SECTION V

PROCESSING INFORMATION

A. Operation

STANDARD FORTRAN MONITOR system

B. Estimated Machine Time

T = time in minutes

ISZ = number of strips

JSZM = total number of reduced velocities

MSZ = number of Mach numbers

n = number of sets (decks) of input data

$$T = 1.0 + .02 \left[(ISZ \cdot MSZ \cdot JSZM)_1 + (ISZ \cdot MSZ \cdot JSZM)_2 + \cdots + (ISZ \cdot MSZ \cdot JSZM)_n \right]$$

C. Machine Components Used

Core storage, about 5300

Standard FORTRAN input tape (NTAPE 2)

Standard FORTRAN output print tape (NTAPE 3)

Standard FORTRAN output punch tape (NTAPE 7)

SECTION VI

PROGRAM NOTES

A. Subroutines Used

RDLN, reads and prints title cards

AEROP4, punch AIC matrix

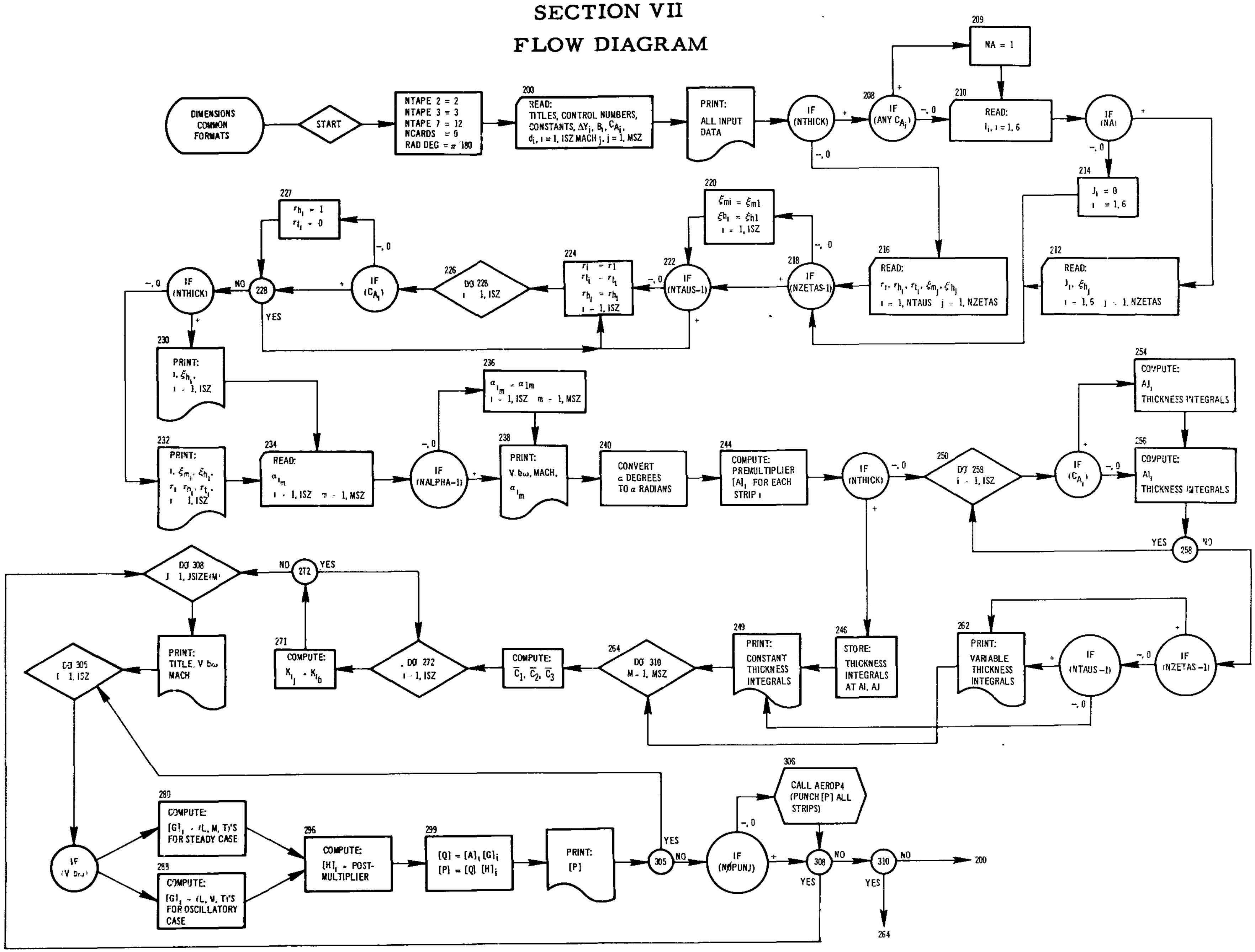
BINPU, column binary punch

All other subroutines are on library tapes

B. Generalized Tapes

Input, print,and punch tapes in this coding are defined as Units 2, 3, and 12, respectively; however, these may be altered by placing the desired units on symbolic cards HM110060, HM110061, and HM110062.

SECTION VII
FLOW DIAGRAM



SECTION VIII

SYMBOLIC LISTING

Some of the symbols used in the program are defined as follows:

FORTRAN Symbols	Definition
NTHRY	Option--theory used for $\overline{C}_1$, $\overline{C}_2$
NTHICK	Option--thickness integrals given or computed
NALPHA	Option--α's constant or vary
NTAUS	Option--τ's constant or vary
NZETAS*	Option--ξ's constant or vary
NØ PUNJ	Option--punching or no punching
ISZ	Number of strips
MSZ	Number of Mach numbers
J SIZE (M)	Number of reduced velocities for Mach number
JSZ	Number of reduced velocities for a Mach number
SEC LAM	sec Λ
BR	b_r
S	s
CAP S	S
C BAR	$\bar{c}$

*Please, no remarks about our Greek!

FORTRAN Symbols	Definition
C BAR 1	$\bar{C}_1$
C BAR 2	$\bar{C}_2$
RAD DEG	$\pi/180.0$ (program constant)
DELTA Y(I)	Δy for strip i
B (I)	b for strip i
CA (I)	c_a for strip i
D (I)	d for strip i
EMACH (M)	m'th Mach number
EKR (J, M)	$1/k_r = (V/b_r\omega)$ for reduced velocity j, for m'th Mach number
EI (N)	I series (thickness integrals)
EJ (N)	J series (thickness integrals)
AI (I, N)	I series for strip i
AJ (I, N)	J series for strip i
ZETA H (I)	ξ_h for strip i
ZETA M (I)	ξ_m for strip i
TAU (I)	τ for strip i
TAU H (I)	τ_h for strip i
TAU T (I)	τ_t for strip i
ALPHA (I, M)	α for strip i, for m'th Mach number
EK (I, N)	K series for strip i

SYMBOLIC LISTING (continued)

FORTRAN Symbols	Definition
CØNST (I)	$4(b/b_r)^2\ \Delta y/s$ for strip i
A (I, N, K)	Premultiplying matrix in oscillatory coefficients matrix equation
G (N, K)	Real, oscillatory leading edge coefficient matrix
GI (N, K)	Imaginary matrix
H (N, K)	Postmultiplying matrix in oscillatory coefficients matrix equation
Q (N, K)	Working array
QI (N, K)	Working array
P (N, K)	AIC matrix, complex

The symbolic listing of the program is shown on the following pages.

```
     AERODYNAMIC  INFLUENCE  COEFFICIENTS  BY  PISTON  THEORY.                4/20/62

                                                                        HM110002
                                                                        HM110003
C  (DIM. FOR (I) )        I=25                                          HM110004
      DIMENSION  A(25,3,3),DELTAY(25), B(25),  TAU(25), ZETAM(25),      HM110005
     1           AJ(25,6), CONST(25), CA(25), TAUH(25), ZETAH(25),      HM110006
     2           AI(25,6), EK(25,6) ,  D(25), TAUT(25)                  HM110007
C  (DIM. FOR (M),(J),(I),--MIXED)      M=15,J=20,I=25                   HM110008
      DIMENSION EKR(20,15),ALPHA(25,15),E MACH(15),J SIZE(15)           HM110009
C  (DIM. FOR CONSTANT ARRAYS)                                           HM110010
      DIMENSION  G(3,3), GI(3,3), H(3,3), P(3,6,25), Q(3,3), QI(3,3)    HM110011
     1,EJ(6),EI(6)                                                      HM110012
                                                                        HM110013
      COMMON EKR,ALPHA,E MACH,J SIZE,G,GI,H,P,PI,Q,QI,EJ                HM110014
     1,EI,A,AJ,AI,EK,DELTA Y,B,CA,D,TAU,TAU H,TAU T,ZETA M              HM110015
     2,ZETA H,CONST                                                     HM110016
                                                                        HM110017
    1 FORMAT  (18I4)                                                    HM110018
    2 FORMAT  (6E12.8)                                                  HM110019
    3 FORMAT  (1H0  33X, 35HAERODYNAMIC INFLUENCE COEFFICIENTS          HM110020
     1         16HBY PISTON THEORY        )                             HM110021
    4 FORMAT  (1H   34X, 36H(WITH VAN DYKES QUASI-STEADY THEORY         HM110022
     1         18H FINAGLING FACTOR)      )                             HM110023
    5 FORMAT  (1H0 54X, 10HINPUT DATA  // 1H  44X, 1I2, 7H STRIPS  / 1H HM110024
     1         44X, 1I2, 13H MACH NUMBERS  / 1I47, 16H REDUCED FREQUEN  HM110025
     2         14HCIES (TOTAL)   / 1H0 44X, 15HSECANT LAMBDA = 1E16.8,  HM110026
     3         /1H  55X, 4HBR =  1E16.8, / 1H  56X, 3HS =  1E16.8 / 1H  HM110027
     4         56X, 3HS =  1E16.8  / 1H  52X, 7HC BAR =  1E16.8 / 1H0   HM110028
     5         19X, 5HSTRIP  6X, 11HDELTA Y (I)  12X, 4HB(I)  15X,      HM110029
     6          5HCA(I)  16X, 4HD(I)  //(1H 1I22,  2E20.8, 1E19.8,      HM110030
     7          1E21.8 )  )                                             HM110031
    6 FORMAT  ( 1H0 51X, 18HSTRIP          XI H   // (1H  1I54, 1E19.8)) HM110032
    7 FORMAT  (1H0 14X, 5HSTRIP 7X, 6H XI M   11X, 6H XI H   13X,       HM110033
     1          3HTAU  13X, 5HTAU H  12X, 5HTAU T  //  (1H  1I17, 2X,   HM110034
     2          5E17.8  )  )                                            HM110035
    8 FORMAT  (1H0 48X, 13HMACH NUMBER =  1F16.8  / (1H  53X, 8H1/K(R) =HM110036
     1          1E16.8  )  )                                            HM110037
    9 FORMAT  (1H  11X, 29HALPHA ZERO SERIES (DEGREES) =  6(1F8.2, 3X ) HM110038
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AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY. 4/20/62

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    1          / (1H  40X,  6(1F8.2, 3X) )  )
   10 FORMAT  (1H0  33X, 38HGIVEN THICKNESS INTEGRALS (CONSTANT)
    1          16H FOR ALL STRIPS)    )
   11 FORMAT  (1H0 32X, 38HCOMPUTED THICKNESS INTEGRALS (CONSTANT
    1          16H FOR ALL STRIPS)    )
   12 FORMAT  (1H0 45X, 28HCOMPUTED THICKNESS INTEGRALS    )
   13 FORMAT  (1H0 5X, 5HSTRIP 7X, 4HJ(1) 12X, 4HJ(2) 12X, 4HJ(3) 12X,
    1          4HJ(4)  12X, 4HJ(5) 12X, 4HJ(6) // (1I9, 3X, 6E16.8) )
   14 FORMAT  (1H0 5X, 5HSTRIP 7X, 4HI(1) 12X, 4HI(2) 12X, 4HI(3) 12X,
    1          4HI(4)  12X, 4HI(5) 12X, 4HI(6) // (1I9, 3X, 6E16.8) )
   15 FORMAT  (1H1 )
   16 FORMAT  (1H0 53X, 11HSTEADY CASE  // 1H  52X, 6HMACH =  1F 16.8,
    1          // 1H  50X, 17H1/K(R) = INFINITY  // 1I57, 7HSTRIPS    )
   17 FORMAT  (1H0 51X, 16HOSCILLATORY CASE  // 1H  49X, 6HMACH = 1F16.8
    1          // 1H  47X,  8H1/K(R) = 1E16.8  // 1I57, 7HSTRIPS    )
   18 FORMAT  (1H0 49X, 3HCH( I11, 8H) SIZE =  I12, 3H BY  I12  )
   19 FORMAT  (1H  30X, 3E18.8)
   20 FORMAT  (1H  3X, 2E16.8, 1HI 2E16.8, 1HI  2E16.8, 1HI )
   21 FORMAT  (1H 19X, 2E16.8, 1HI 2E16.8, 1HI   )
   22 FORMAT (1H   39X,  2E18.8)

      NTAPE2=2
      NTAPE3=3
      NTAPE7=12
      NCARDS=0
      RAD DEG=3.14159265 / 180.
  200 CALL RDLN  (NTAPE2, NTAPE3, 1)
      CALL CDLN  (NTAPE2, NTAPE3, 2)
      READ INPUT TAPE NTAPE2, 1, NTHRY, NTHICK, NALPHA, NTAUS, NZETAS
      READ INPUT TAPE NTAPE2, 1, ISZ, MSZ, NOPUNJ, (JSIZE(M),M=1,MSZ)
      READ INPUT TAPE NTAPE2, 2, SECLAM, BR, S, CAPS, CBAR
      READ INPUT TAPE NTAPE2, 2,  (DELTAY(I),I=1,ISZ)
      READ INPUT TAPE NTAPE2, 2,  (B(I),I=1,ISZ)
      READ INPUT TAPE NTAPE2, 2,  (CA(I),I=1,ISZ)
      READ INPUT TAPE NTAPE2, 2,  (D(I),I=1,ISZ)
      READ INPUT TAPE NTAPE2, 2,  (EMACH(I),I=1,MSZ)

      JDOG=0
```

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      DO  202  I=1,MSZ                                                    HM110077
202     JDOG=JDOG+JSIZE(I)                                                HM110078
      WRITE OUTPUT TAPE NTAPE3, 3                                         HM110079
      IF (NTHRV)  206,206,204                                             HM110080
204   WRITE OUTPUT TAPE NTAPE3, 4                                         HM110081
206   WRITE OUTPUT TAPE NTAPE3, 5, ISZ, MSZ, JDOG, SECLAM, BR, S, CAPS,   HM110082
     1                            CBAR,  (I, DELTAY(I), B(I), CA(I),      HM110083
     2                            D(I),I=1,ISZ)                           HM110084
      IF  (NTHICK)     216,216,208                                        HM110085
208   NA=0                                                                HM110086
      DO  210  I=1,ISZ                                                    HM110087
        IF (CA(I))   210,210,209                                          HM110088
209     NA=1                                                              HM110089
210     CONTINUE                                                          HM110090
      READ INPUT TAPE NTAPE2, 2,  (EI(I),I=1,6)                           HM110091
      IF  (NA)         214,214,212                                        HM110092
212   READ INPUT TAPE NTAPE2, 2,  (EJ(I),I=1,6)                           HM110093
      READ INPUT TAPE NTAPE2, 2,  (ZETAH(I),I=1,NZETAS)                   HM110094
      GOTO  216                                                           HM110095
214   DO  215  I=1,6                                                      HM110096
215     EJ(I)=0.                                                          HM110097
      GOTO  218                                                           HM110098
216   READ INPUT TAPE NTAPE2, 2,  (TAU(I), TAUH(I),TAUT(I),I=1,NTAUS)     HM110099
      READ INPUT TAPE NTAPE2, 2,  (ZETAM(I),ZETAH(I),I=1,NZETAS)          HM110100
218   IF (NZETAS-1)  220,220,222                                          HM110101
220   DO  221  I=1,ISZ                                                    HM110102
        ZETAM(I)=ZETAM(1)                                                 HM110103
221     ZETAH(I)=ZETAH(1)                                                 HM110104
                                                                          HM110105
222   IF (NTAUS-1)   224,224,226                                          HM110106
224   DO  225  I=1,ISZ                                                    HM110107
        TAU(I)=TAU(1)                                                     HM110108
        TAUH(I)=TAUH(1)                                                   HM110109
225     TAUT(I)=TAUT(1)                                                   HM110110
                                                                          HM110111
226   DO  228  I=1,ISZ                                                    HM110112
        IF (CA(I))   227,227,228                                          HM110113
227     ZETAH(I)=1.                                                       HM110114
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      AERODYNAMIC  INFLUENCE  COEFFICIENTS  BY  PISTON  THEORY.          4/20/62

        TAUT(I)=0.                                                       HM110115
  228   CONTINUE                                                         HM110116
                                                                         HM110117
        IF  ( NTHICK )   232,232,230                                     HM110118
  230 WRITE OUTPUT TAPE NTAPE3, 6, (I, ZETAH(I),I=1,ISZ)                 HM110119
      GOTO  234                                                          HM110120
  232 WRITE OUTPUT TAPE NTAPE3, 7, (I, ZETAM(I), ZETAH(I), TAU(I),       HM110121
     1                               TAUH(I), TAUT(I), I=1, ISZ  )       HM110122
                                                                         HM110123
  234 READ INPUT TAPE NTAPE2, 2, ((ALPHA(I,M),M=1,MSZ),I=1,NALPHA)       HM110124
      IF  (NALPHA-1) 236,236,238                                         HM110125
  236 DO  237  I=1,ISZ                                                   HM110126
        DO  237  M=1,MSZ                                                 HM110127
  237     ALPHA(I,M)=ALPHA(1,M)                                          HM110128
                                                                         HM110129
  238 DO  240  I=1,MSZ                                                   HM110130
        JSZ=JSIZE(I)                                                     HM110131
      READ INPUT TAPE NTAPE2, 2,  (EKR(J,I),J=1,JSZ)                     HM110132
      WRITE OUTPUT TAPE NTAPE3, 8,  EMACH(I), (EKR(J,I),J=1,JSZ)         HM110133
      WRITE OUTPUT TAPE NTAPE3, 9,  (ALPHA(J,I),J=1,ISZ)                 HM110134
                                                                         HM110135
      DO  240  J=1,ISZ                                                   HM110136
  240   ALPHA(J,I)=ALPHA(J,I)*RADDEG                                     HM110137
                                                                         HM110138
                                                                         HM110139
      DO  244  I=1,ISZ                                                   HM110140
      CONST(I)=4.0*(B(I)/BR)*(B(I)/BR)*(DELTA Y(I)/S)                    HM110141
      A(I,1,1)=1.0+B(I)/(2.0*D(I) )                                      HM110142
      A(I,1,2)=-B(I)/D(I)                                                HM110143
      A(I,2,1)=-B(I)/(2.0*D(I) )                                         HM110144
      A(I,2,2)=-A(I,1,2)                                                 HM110145
                                                                         HM110146
      IF  ( CA(I) )   244,244,242                                        HM110147
  242 A(I,1,3)=(B(I)/CA(I))*(3.*B(I)/(2.*D(I))-1.)                       HM110148
      A(I,2,3)=-(B(I)/CA(I) )*(3.0*B(I)/(2.0*D(I) ) )                    HM110149
      A(I,3,1)=0.0                                                       HM110150
      A(I,3,2)=0.0                                                       HM110151
      A(I,3,3)=B(I)/CA(I)                                                HM110152
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      AERODYNAMIC  INFLUENCE  COEFFICIENTS  BY  PISTON  THEORY.           4/20/62

  244 CONTINUE                                                            HM110153
                                                                          HM110154
      IF  ( NTHICK )      250,250,246                                     HM110155
  246 NUMBER=1                                                            HM110156
      DO  248  I=1,ISZ                                                    HM110157
        DO  248  N=1,6                                                    HM110158
          AI(I,N)=EI(N)                                                   HM110159
          AJ(I,N)=0.                                                      HM110160
          IF  ( CA(I) )   248,248,247                                     HM110161
  247     AJ(I,N)=EJ(N)                                                   HM110162
          NUMBER=I                                                        HM110163
  248     CONTINUE                                                        HM110164
      WRITE OUTPUT TAPE NTAPE3, 10                                        HM110165
  249 WRITE OUTPUT TAPE NTAPE3, 13, NUMBER,  (AJ(NUMBER,N),N=1,6)         HM110166
      WRITE OUTPUT TAPE NTAPE3, 14, NUMBER,  (AI(NUMBER,N),N=1,6)         HM110167
      GOTO  264                                                           HM110168
                                                                          HM110169
  250 NUMBER=1                                                            HM110170
      DO  258  I=1,ISZ                                                    HM110171
      T=TAU H(I)-TAU T(I)                                                 HM110172
      IF  ( CA(I) )   252,252,254                                         HM110173
  252 DO  253  K=1,6                                                      HM110174
  253   AJ(I,K)=0.                                                        HM110175
      GOTO   256                                                          HM110176
                                                                          HM110177
  254 NUMBER=I                                                            HM110178
      AJ(I,1)=-0.5*T                                                      HM110179
      AJ(I,2)=-0.25*T*(1.0+ZETA H(I))                                     HM110180
      AJ(I,3)=-(1.0/6.0)*T*(1.0+ZETA H(I)+ZETA H(I)*ZETA H(I) )           HM110181
      AJ(I,4)=0.25*T*T/(1.0-ZETA H(I) )                                   HM110182
      AJ(I,5)=0.125*T*T*(1.0+ZETA H(I) )/(1.0-ZETA H(I) )                 HM110183
      AJ(I,6)=(1.0/12.0)*T*T*(1.0+ZETA H(I)+ZETA H(I)*ZETA H(I) )         HM110184
     1    /(1.0-ZETA H(I) )                                               HM110185
                                                                          HM110186
  256 CONTINUE                                                            HM110187
      TS=(TAU(I)-TAU H(I))*(TAU(I)-TAU H(I))                              HM110188
      AI(I,1)=(TAU H(I)/2.0)+AJ(I,1)                                      HM110189
      AI(I,2)=-(TAU(I)/3.0)*ZETA H(I)+(TAU H(I)/6.0)                      HM110190
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AERODYNAMIC  INFLUENCE  COEFFICIENTS  BY  PISTON  THEORY.                     4/20/62

 1     *(2.0*ZETA H(I)+ZETA M(I) )+AJ(I,2)                                   HM110191
       AI(I,3)=-(TAU(I)/12.0)*ZETA H(I)*(3.0*ZETA H(I)+2.0                   HM110192
 1     *ZETA M(I) )+(TAU H(I)/12.0)*(3.0*ZETA H(I)*ZETA H(I)                 HM110193
 2     +2.0*ZETA H(I)*ZETA M(I)+ZETA M(I)*ZETA M(I) )+AJ(I,3)                HM110194
       AI(I,4)=(TAU(I)*TAU(I)/(3.0*ZETA M(I) ))+(1.0/3.0)*TS                 HM110195
 1     *(ZETA H(I)-ZETA M(I) )+AJ(I,4)                                       HM110196
       AI(I,5)=(TAU(I)*TAU(I)/12.0)+(1.0/12.0)*TS*(3.0                       HM110197
 1     *ZETA H(I)+ZETA M(I) )/(ZETA H(I)-ZETA M(I) )+AJ(I,5)                 HM110198
       AI(I,6)=(TAU(I)*TAU(I)/30.0)*ZETA M(I)+(1.0/30.0)                     HM110199
 1     *TS*(6.0*ZETA H(I)*ZETA H(I)+3.0*ZETA H(I)*ZETA M(I)                  HM110200
 2     +ZETA M(I)*ZETA M(I) )/(ZETA H(I)-ZETA M(I) )+AJ(I,6)                 HM110201
258    CONTINUE                                                              HM110202
                                                                             HM110203
       IF  (NZETAS-1)      260,260,262                                       HM110204
260    IF  (NTAUS-1)       261,261,262                                       HM110205
261    WRITE OUTPUT TAPE NTAPE3, 11                                          HM110206
       GOTO  249                                                             HM110207
                                                                             HM110208
262    WRITE OUTPUT TAPE NTAPE3, 12                                          HM110209
       WRITE OUTPUT TAPE NTAPE3, 13, (I, (AJ(I,N),N=1,6),I=1,ISZ)            HM110210
       WRITE OUTPUT TAPE NTAPE3, 14, (I, (AI(I,N),N=1,6),I=1,ISZ)            HM110211
                                                                             HM110212
264    DO  310  M=1,MSZ                                                      HM110213
       EMS=E MACH(M)*E MACH(M)                                               HM110214
       SECS=SEC LAM*SEC LAM                                                  HM110215
       IF  (NTHRY)       266,266,268                                         HM110216
266    CBAR1=1.                                                              HM110217
       CBAR2=(1.4+1.0)/4.0                                                   HM110218
       GOTO  270                                                             HM110219
268    CBAR1= EMACH(M) / SQRTF (EMS-SECS)                                    HM110220
       CBAR2= (    EMS*EMS*(1.4+1.0)-4.0*SECS*(EMS-SECS)    ) /(4.0*         HM110221
 1     (EMS-SECS)*(EMS-SECS) )                                               HM110222
270    CBAR3= (1.4+1.)  /12.                                                 HM110223
                                                                             HM110224
       DO  272  I=1,ISZ                                                      HM110225
       EK(I,1)=(1.0/E MACH(M) )*(CBAR1+2.0*CBAR2*E MACH(M)*AI(I,1)           HM110226
 1     +3.0*CBAR3*EMS*(AI(I,4)+ALPHA(I,M)*ALPHA(I,M) ) )                     HM110227
       EK(I,2)=(1.0/E MACH(M) )*(CBAR1+4.0*CBAR2*E MACH(M)                   HM110228
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      AERODYNAMIC  INFLUENCE  COEFFICIENTS  BY  PISTON  THEORY.            4/20/62

      1     *AI(I,2)+3.0*CBAR3*EMS*(2.0*AI(I,5)+ALPHA(I,M)*ALPHA(I,M)))    HM110229
       EK(I,3)=(4.0/(3.0*E MACH(M)))*(CBAR1+6.0*CBAR2*E MACH(M)*AI(I,3)  HM110230
      1     +3.0*CBAR3*EMS*(3.0*AI(I,6)+ALPHA(I,M)*ALPHA(I,M)))             HM110231
                                                                           HM110232
       IF  ( CA(I) )   272,272,271                                         HM110233
   271 EK(I,4)=(1./EMACH(M) )*(CBAR1*(1.0-ZETAH(I) )+2.*CBAR2              HM110234
      1     *EMACH(M)*AJ(I,1)+3.0*CBAR3*EMS*(AJ(I,4)+ALPHA(I,M)            HM110235
      2     *ALPHA(I,M)*(1.0-ZETA H(I) )))                                 HM110236
       EK(I,5)=(1.0/EMACH(M) ) * (CBAR1*(1.0-ZETA H(I)*ZETA H(I))          HM110237
      1     +4.0*CBAR2*EMACH(M)*AJ(I,2)+3.0*CBAR3*EMS                      HM110238
      2     *(2.0*AJ(I,5)+ALPHA(I,M)*ALPHA(I,M)*(1.0-ZETAH(I)*ZETAH(I)) ))HM110239
       EK(I,6)=(4.0/(3.0*E MACH(M) )) * (CBAR1*(1.0-ZETA H(I)              HM110240
      1     *ZETA H(I)*ZETA H(I) )+6.0*CBAR2*EMACH(M)*AJ(I,3)              HM110241
      2     +3.0*CBAR3*EMS*(3.0*AJ(I,6)+ALPHA(I,M)*ALPHA(I,M)              HM110242
      3     *(1.0-ZETA H(I)*ZETA H(I)*ZETA H(I) )))                        HM110243
   272 CONTINUE                                                            HM110244
                                                                           HM110245
       JSZ=JSIZE(M)                                                        HM110246
       DO  308  J=1,JSZ                                                    HM110247
       WRITE OUTPUT TAPE NTAPE3, 15                                        HM110248
       WRITE OUTPUT TAPE NTAPE3, 3                                         HM110249
       IF  ( NTHRY )      275,275,274                                      HM110250
   274 WRITE OUTPUT TAPE NTAPE3, 4                                         HM110251
   275 IF  ( EKR(J,M) )  276,276,277                                       HM110252
   276 WRITE OUTPUT TAPE NTAPE3, 16, EMACH(M), ISZ                         HM110253
       GOTO  278                                                           HM110254
   277 WRITE OUTPUT TAPE NTAPE3, 17, EMACH(M), EKR(J,M), ISZ                HM110255
   278 DO  305  I=1,ISZ                                                    HM110256
       IF  ( EKR(J,M) )   280,280,288                                      HM110257
   280 G(1,1)=0.                                                           HM110258
       G(2,1)=0.0                                                          HM110259
       BB=BR*BR/(B(I)*B(I) )                                               HM110260
       G(1,2)=-EK(I,1)*BB                                                  HM110261
       G(2,2)=-EK(I,2)*BB                                                  HM110262
       IF  ( CA(I) )   284,284,282                                         HM110263
   282 G(1,3)=-EK(I,4)*BB                                                  HM110264
       G(2,3)=-EK(I,5)*BB                                                  HM110265
       G(3,1)=0.0                                                          HM110266
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      G(3,2)=-(EK(I,5)-2.0*EK(I,4)*ZETA H(I) )*BB                        HM110267
      G(3,3)=G(3,2)                                                      HM110268
  284 DO  286  IT=1,3                                                    HM110269
      DO  286  IN=1,3                                                    HM110270
  286 GI(IT,IN)=0.                                                       HM110271
      GOTO  292                                                          HM110272
  288 E1K=EKR(J,M)*BR/B(I)                                               HM110273
      E1KS=E1K*E1K                                                       HM110274
      G(1,1)=0.0                                                         HM110275
      GI(1,1)=-EK(I,1)*E1K                                               HM110276
      G(1,2)=-EK(I,1)*E1KS                                               HM110277
      GI(1,2)=-EK(I,2)*E1K                                               HM110278
      G(2,1)=0.0                                                         HM110279
      GI(2,1)=-EK(I,2)*E1K                                               HM110280
      G(2,2)=-EK(I,2)*E1KS                                               HM110281
      GI(2,2)=-EK(I,3)*E1K                                               HM110282
      IF  ( CA(I) )   292,292,290                                        HM110283
                                                                         HM110284
  290 G(1,3)=-EK(I,4)*E1KS                                               HM110285
      GI(1,3)=-(EK(I,5)-2.0*EK(I,4)*ZETA H(I) )*E1K                      HM110286
      G(2,3)=-EK(I,5)*E1KS                                               HM110287
      GI(2,3)=-(EK(I,6)-2.0*EK(I,5)*ZETA H(I) )*E1K                      HM110288
      G(3,1)=0.0                                                         HM110289
      GI(3,1)=-(EK(I,5)-2.0*EK(I,4)*ZETA H(I) )*E1K                      HM110290
      G(3,2)=-(EK(I,5)-2.0*EK(I,4)*ZETA H(I) )*E1KS                      HM110291
      GI(3,2)=-(EK(I,6)-2.0*EK(I,5)*ZETA H(I) )*E1K                      HM110292
      G(3,3)=-(EK(I,5)-2.0*EK(I,4)*ZETA H(I) )*E1KS                      HM110293
      GI(3,3)=-(EK(I,6)-4.0*EK(I,5)*ZETA H(I)+4.0*EK(I,4)*ZETA H(I)      HM110294
     1    *ZETA H(I) )*E1K                                               HM110295
  292 CONTINUE                                                           HM110296
                                                                         HM110297
      NU=2                                                               HM110298
      IF  ( CA(I) )   295,295,294                                        HM110299
  294 NU=3                                                               HM110300
  295 DO  296  IT=1,NU                                                   HM110301
      DO  296  IN=1,NU                                                   HM110302
  296 H(IT,IN)=A(I,IN,IT)                                                HM110303
      H(3,1)=H(2,2)                                                      HM110304
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      H(3,2)=-(H(3,1)+H(3,3) )                                          HM110305
                                                                        HM110306
C     MULT A(I,N,N)*(  G(N,N)+GI(N,N)  )*H(N,N)    STORE IN P(N,N),PI(N,N) HM110307
      DO  297  K=1,NU                                                   HM110308
      DO  297  L=1,NU                                                   HM110309
      Q (K,L)=0.0                                                       HM110310
      QI(K,L)=0.0                                                       HM110311
      DO  297  M1=1,NU                                                  HM110312
      Q (K,L)=Q (K,L)+A(I,K,M1)*G (M1,L)                                HM110313
  297 QI(K,L)=QI(K,L)+A(I,K,M1)*GI(M1,L)                                HM110314
      IN=2*NU                                                           HM110315
      DO  299  K=1,NU                                                   HM110316
      DO  299  L=1,IN,2                                                 HM110317
      IT=L/2+1                                                          HM110318
      P(K,L,I)=0.                                                       HM110319
      P(K,L+1,I)=0.                                                     HM110320
      DO  298  M1=1,NU                                                  HM110321
      P(K,L,I)=P(K,L,I)+Q(K,M1)*H(M1,IT)                                HM110322
  298 P(K,L+1,I)=P(K,L+1,I)+QI(K,M1)*H (M1,IT)                          HM110323
      P(K,L,I)=P(K,L,I)*CONST(I)                                        HM110324
  299 P(K,L+1,I)=P(K,L+1,I)*CONST(I)                                    HM110325
      WRITE OUTPUT TAPE NTAPE3, 18,  I, NU, NU                          HM110326
      IF  ( ERR(J,M) )    300,300,302                                   HM110327
  300 CORR=2.*S*CBAR/CAPS                                               HM110328
      DO  301  K=1,NU                                                   HM110329
      DO  301  L=1,IN,2                                                 HM110330
  301 P(K,L,I)=P(K,L,I)*CORR                                            HM110331
      IF ( NU-2)      311,312,311                                       HM110332
  311 WRITEOUTPUT TAPE NTAPE3, 19,  ((P(K,L,I),L=1,IN,2),K=1,NU)        HM110333
      GOTO  305                                                         HM110334
  312 WRITE OUTPUT TAPE NTAPE3, 22, ((P(K,L,I),L=1,IN,2),K=1,NU)        HM110335
      GOTO  305                                                         HM110336
  302 IF  (NU-2)   304,304,303                                          HM110337
  303 WRITE OUTPUT TAPE NTAPE3, 20, ((P(K,L,I),L=1,IN),K=1,NU)          HM110338
      GOTO  305                                                         HM110339
  304 WRITE OUTPUT TAPE  NTAPE3, 21,  ((P(K,L,I),L=1,IN),K=1,NU)        HM110340
  305 CONTINUE                                                          HM110341
      IF ( NOPUNJ )     308,306,308                                     HM110342
```

```
306 CALL AERO P4  (EKR(J,M),EMACH(M),P,ISZ,NCARDS,NTAPE3,NTAPE7,CA)     HM110343
                                                                        HM110344
308 CONTINUE                                                            HM110345
                                                                        HM110346
310 CONTINUE                                                            HM110347
                                                                        HM110348
    GOTO  200                                                           HM110349
    END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY. 4/20/62 PAGE 11

STORAGE NOT USED BY PROGRAM

DEC	OCT	DEC	OCT
2372	04504	30423	73327

STORAGE LOCATIONS FOR VARIABLES APPEARING IN COMMON STATEMENTS

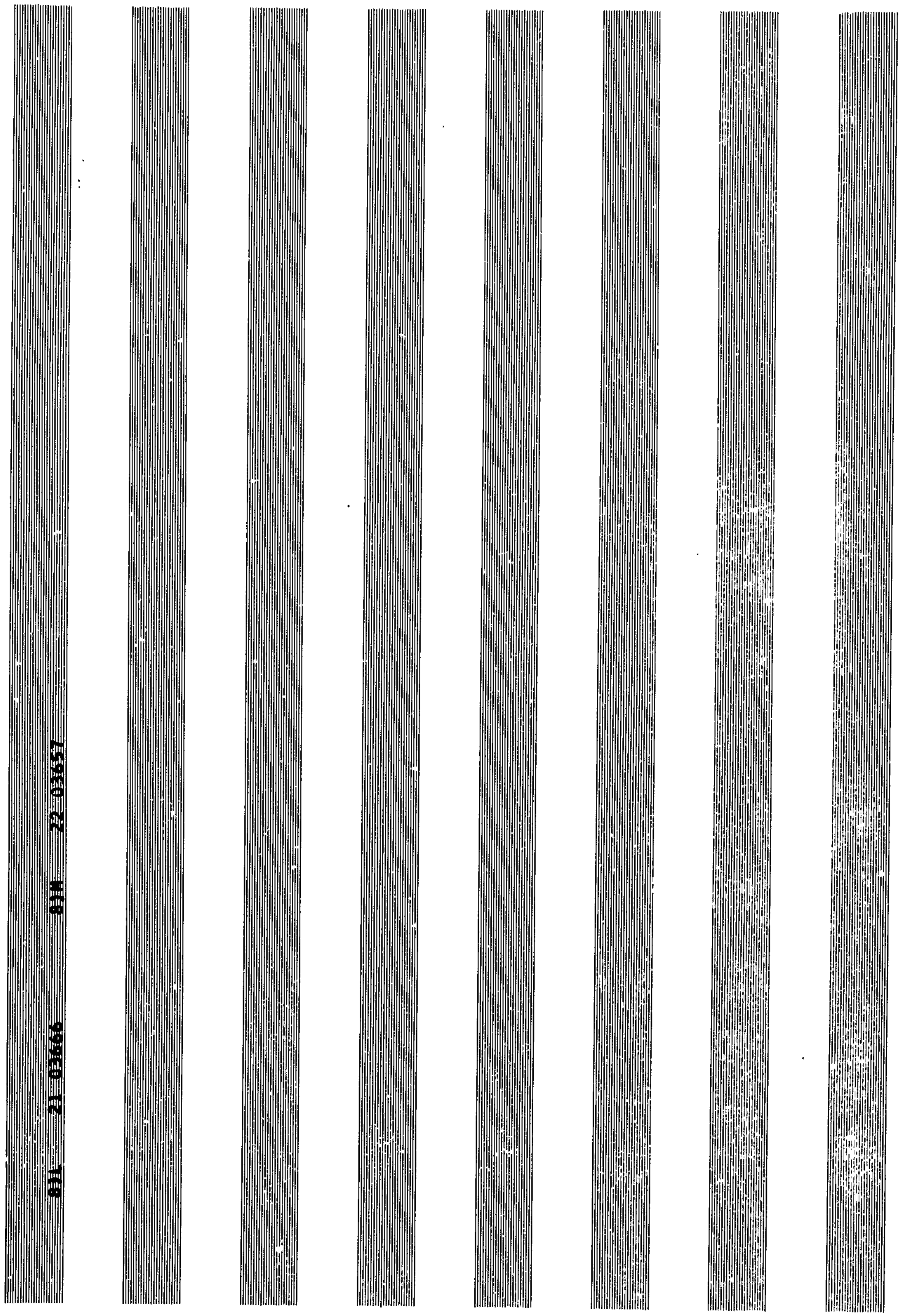
	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
AI	30973	74375	AJ	31123	74623	ALPHA	32261	77005	A	31348	75164
B	30648	73670	CA	30623	73637	CONST	30448	73360	DELTAY	30673	73721
D	30598	73606	EI	31354	75172	EJ	31360	75200	EKR	32561	77461
EK	30823	74147	EMACH	31886	76216	GI	31847	76147	G	31856	76160
H	31838	76136	JSIZE	31871	76177	PI	31379	75223	P	31829	76125
QI	31369	75211	Q	31378	75222	TAUH	30548	73524	TAU	30573	73555
TAUT	30523	73473	ZETAH	30473	73411	ZETAM	30498	73442			

STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENTS

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
BB	2371	04503	BR	2370	04502	CAPS	2369	04501	CBAR1	2368	04500
CBAR2	2367	04477	CBAR3	2366	04476	CBAR	2365	04475	CORR	2364	04474
EIK	2363	04473	EIKS	2362	04472	EMS	2361	04471	IN	2360	04470
I	2359	04467	ISZ	2358	04466	IT	2357	04465	JDOG	2356	04464
JSZ	2355	04463	L	2354	04462	M	2353	04461	MSZ	2352	04460
NALPHA	2351	04457	NA	2350	04456	NCARDS	2349	04455	NOPUNJ	2348	04454
NTAPE2	2347	04453	NTAPE3	2346	04452	NTAPE7	2345	04451	NTAUS	2344	04450
NTHICK	2343	04447	NTHRY	2342	04446	NUMBER	2341	04445	NU	2340	04444
NZETAS	2339	04443	RADDEG	2338	04442	SECLAM	2337	04441	SECS	2336	04440
S	2335	04437	T	2334	04436	TS	2333	04435			

SYMBOLS AND LOCATIONS FOR SOURCE PROGRAM FORMAT STATEMENTS

	EFN	LOC		EFN	LOC		EFN	LOC		EFN	LOC
8)1	1	04400	8)2	2	04376	8)3	3	04374	8)4	4	04354
8)5	5	04334	8)6	6	04214	8)7	7	04202	8)8	8	04151
8)9	9	04133	8)A	10	04112	8)B	11	04072	8)C	12	04052
8)D	13	04042	8)E	14	04015	8)F	15	03770	8)G	16	03766
8)H	17	03741	8)I	18	03714	8)J	19	03703	8)K	20	03677


81L 21 03666
81M 22 03657

LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
1)	2305	04401	2)	1936	03620	3)	1945	03631	4)	32767	77777
6)	1959	03647	C)G0	2313	04411	C)G1	2314	04412	C)100	2315	04413
C)103	2316	04414	C)104	2317	04415	C)106	2318	04416	C)107	2319	04417
C)108	2320	04420	C)10B	2321	04421	C)10D	2322	04422	C)10E	2323	04423
C)162	2324	04424	C)200	2325	04425	C)20A	2326	04426	C)20C	2327	04427
C)20G	2328	04430	C)201	2329	04431	C)20M	2330	04432	C)20N	2331	04433
C)20D	2332	04434	D)128	493	00755	D)12D	503	00767	D)142	1305	02431
C)42L	615	01147	D)430	1022	01776	D)43Q	1221	02305	D)455	1763	03343
C)45G	1844	03464	D)45R	1903	03557	D)45S	1924	03604	D)53Q	1220	02304
D)542	1304	02430	D)555	1762	03342	D)55G	1843	03463	D)62L	614	01146
D)62D	1021	01775	D)655	1923	03603	E)3P	1107	02123	E)4R	1648	03160

LOCATIONS OF NAMES IN TRANSFER VECTOR

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
AEROP4	7	00007	RDLN	1	00001	SQRT	6	00006	(FIL)	5	00005
(FPT)	0	00000	(RTN)	3	00003	(STH)	4	00004	(TSH)	2	00002

ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

AEROP4 RDLN SQRT (FIL) (FPT) (RTN) (STH) (TSH)

EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC
200	33	00026	202	74	00207	204	77	00224	206	78	00230
208	85	00302	209	88	00313	210	89	00315	212	96	00334
214	107	00361	215	108	00362	216	110	00367	218	120	00423
220	121	00427	221	123	00434	222	124	00440	224	125	00444
225	128	00453	226	129	00457	227	131	00465	228	133	00471
230	135	00477	232	141	00520	234	146	00550	236	154	00602
237	156	00616	238	157	00626	240	176	00770	242	184	01066
244	189	01125	246	191	01134	247	197	01161	248	199	01165
249	201	01202	250	214	01235	252	218	01257	253	219	01257

AERODYNAMIC INFLUENCE COEFFICIENTS BY PISTON THEORY. 4/20/62

254	221	01265	256	228	01364	258	236	01566	260	238	01577
261	239	01603	262	241	01610	264	256	01666	266	260	01705
268	263	01714	270	265	01751	271	271	02124	272	274	02306
274	280	02356	275	281	02362	276	282	02365	277	285	02402
278	287	02420	280	289	02435	282	295	02464	284	300	02512
286	302	02513	288	304	02523	290	315	02572	292	325	02722
294	328	02730	295	329	02732	296	331	02752	297	340	03036
298	349	03165	299	351	03201	300	355	03234	301	358	03272
311	360	03307	312	368	03362	302	376	03431	303	377	03436
304	385	03503	305	392	03543	306	394	03560	308	396	03605
310	397	03613									

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                                                                      4/20/62
                                                                    HM110351
      SUBROUTINE  RDLN  (NTAPE2, NTAPE3, I )                        HM110352
    1 FORMAT(80H                                                    HM110353
     1                            )                                 HM110354
    2 FORMAT(1H1)                                                   HM110355
    3 FORMAT  ( 1H0 )                                               HM110356
                                                                    HM110357
      READ INPUT TAPE NTAPE2, 1                                     HM110358
      GOTO   (4,5),I                                                HM110359
                                                                    HM110360
    4 WRITE OUTPUT TAPE NTAPE3, 2                                   HM110361
      GOTO  6                                                       HM110362
                                                                    HM110363
    5 WRITE OUTPUT TAPE NTAPE3, 3                                   HM110364
                                                                    HM110365
    6 WRITE OUTPUT TAPE NTAPE3, 1                                   HM110366
                                                                    HM110367
      RETURN
      END(1,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

STORAGE NOT USED BY PROGRAM

DEC	OCT	DEC	OCT
76	00114	32561	77461

SYMBOLS AND LOCATIONS FOR SOURCE PROGRAM FORMAT STATEMENTS

	EFN	LOC		EFN	LOC		EFN	LOC		EFN	LOC
8)1	1	00112	8)2	2	00073	8)3	3	00072			

LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
6)	52	00064	C)GO	75	00113	E)1	28	00034			

LOCATIONS OF NAMES IN TRANSFER VECTOR

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
(FIL)	3	00003	(RTN)	1	00001	(STH)	2	00002	(TSH)	0	00000

ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

(FIL) (RTN) (STH) (TSH)

EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC
4	8	00035	5	10	00044	6	11	00052			

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```
      SUBROUTINE  AERO P4  (VBRW,XMACH,CH,ISTRIP,NSTART,NTAPE3,NTAPE7,  HM110369
     1                     CA)                                          HM110370
      DIMENSION  CH(3,6,25), A(22), CA(25)                              HM110371
                                                                        HM110372
    1 FORMAT  (2E12.8, 48X, 4HHM11   1I4)                               HM110373
    2 FORMAT  (1H0 40X, 24H PUNCHED CARDS NOS. HM11  1I4,               HM110374
     1         10H THRU HM11  1I4 )                                     HM110375
    3 FORMAT  (2I4,  64X,  4HHM11   1I4 )                               HM110376
                                                                        HM110377
  8   BCDZ =603044010160                                                HM110378
      IORG=1                                                            HM110379
      IS=NSTART                                                         HM110380
      NITS=1                                                            HM110381
      IF (VBRW)   4,4,5                                                 HM110382
    4 NITS=2                                                            HM110383
    5 WRITE OUTPUT TAPE NTAPE7, 1, VBRW, XMACH, IS                      HM110384
      IS=IS+1                                                           HM110385
      K=0                                                               HM110386
      DO  7  I=1,ISTRIP                                                 HM110387
        IF  (CA(I))   7,7,6                                             HM110388
    6 K=K+1                                                             HM110389
    7 K=K+2                                                             HM110390
      WRITE OUTPUT TAPE NTAPE7, 3, K, ISTRIP, IS                        HM110391
      IS=IS+1                                                           HM110392
                                                                        HM110393
      DO  8  I=1,22                                                     HM110394
    8   A(I)=0.                                                         HM110395
      M=0                                                               HM110396
      DO  15  I=1,ISTRIP                                                HM110397
        NUTS=4                                                          HM110398
        IF  (CA(I))   10,10,9                                           HM110399
    9   NUTS=6                                                          HM110400
   10   NURTS=NUTS/2                                                    HM110401
        DO  14  L=1,NUTS,NITS                                           HM110402
          DO  13  J=1,NURTS                                             HM110403
            M=M+1                                                       HM110404
   18       IF (M-23)   13,11,11                                        HM110405
   11       M=M-22                                                      HM110406
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      CALL BINPU  (A,22,IORG,BCDZ,IS,NTAPE7)                          HM110407
      IORG=IORG+22                                                    HM110408
      IS=IS+1                                                         HM110409
      DO  12  N=1,22                                                  HM110410
12      A(N)=0.                                                       HM110411
   GOTO  18                                                           HM110412
13      A(M)=CH(J,L,I)                                                HM110413
14   M=M+K-NURTS                                                      HM110414
15 M=M+NURTS                                                          HM110415
   M=M-K                                                              HM110416
   IF  (M)    17,17,16                                                HM110417
16 CALL BINPU  (A,M,IORG,BCDZ,IS,NTAPE7)                              HM110418
   IS=IS+1                                                            HM110419
17 CALL BINPU  (A,0,0,BCDZ,IS,NTAPE7)                                 HM110420
   WRITE OUTPUT TAPE NTAPE3, 2, NSTART, IS                            HM110421
   NSTART=IS+1                                                        HM110422
   RETURN                                                             HM110423
                                                                      HM110424
   END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

```
                                                                    6/12/62      PAGE 3

                                   STORAGE NOT USED BY PROGRAM

           DEC   OCT              DEC   OCT
           335 00517            32561 77461

              STORAGE LOCATIONS FOR VARIABLES APPEARING IN DIMENSION AND EQUIVALENCE STATEMENTS

           DEC   OCT              DEC   OCT              DEC   OCT              DEC   OCT
       A   334 00516

       STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENTS

           DEC   OCT              DEC   OCT              DEC   OCT              DEC   OCT
    BCDZ   312 00470      IORG    311 00467         I    310 00466        IS    309 00465
       K   308 00464         M    307 00463      NITS    306 00462     NURTS    305 00461
    NUTS   304 00460

                    SYMBOLS AND LOCATIONS FOR SOURCE PROGRAM FORMAT STATEMENTS

           EFN   LOC              EFN   LOC              EFN   LOC              EFN   LOC
     8)1     1 00445       8)2      2 00440       8)3      3 00421

                    LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

           DEC   OCT              DEC   OCT              DEC   OCT              DEC   OCT
      1)   295 00447        2)    253 00375        3)    262 00406        6)    264 00410
      9)   294 00446      C)GO    299 00453      C)G2    300 00454     C)1GO    301 00455
   C)200   302 00456     C)201    303 00457     D)20C    145 00221

                               LOCATIONS OF NAMES IN TRANSFER VECTOR

           DEC   OCT              DEC   OCT              DEC   OCT              DEC   OCT
   BINPU     2 00002     (FIL)      1 00001     (STH)      0 00000

                          ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY
```

BINPU (FIL) (STH)

EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC
4	12	00061	5	13	00063	6	19	00111	7	20	00114
8	25	00137	9	30	00163	10	31	00165	18	35	00232
11	36	00237	12	42	00261	13	44	00266	14	45	00276
15	46	00311	16	49	00333	17	52	00347			

```
     BINPU ROUTINE TO WRITE COL BIN CARDS ON TAPE. FIB11                               4/20/62     PAGE 1

                                    ********************************************************************HM110429
                                    *                                                                   HM110430
                                    * CALLING SEQUENCE                                                  HM110431
                                    *       TSX      BINPU,4                                            HM110432
                                    *       TSX      LOC (ARRAY TO BE PUNCHED)                          HM110433
                                    *       TSX      LOC (NO. WORDS TO PUNCH)                           HM110434
                                    *       TSX      LOC (CARD ORIGIN FOR 1ST CARD)                     HM110435
                                    *      *TSX      LOC (SEQ NO. OF 1ST CARD)                          HM110436
                                    *      *TSX      LOC (BCD ID FOR THIS DECK, 1ST AND 2ND CHARACTER BLANKS) HM110437
                                    *       TSX      LOC (OUTPUT TAPE NUMBER)                           HM110438
                                    *****CONTRARY TO BELOW, NO ITEMS MAY BE OMITTED IN THIS MODIFICATION.   HM110439
                                    *                                                                   HM110440
                                    * ITEMS MARKED (*) MAY BE DELETED. BCD ID WILL BE                   HM110441
                                    *       UNCHANGED AND SEQ. NOS. WILL BE CONTINUOUS STARTING         HM110442
                                    *       FROM  000. ALSO ORDER MAY BE SWITCHED.                      HM110443
                                    *                                                                   HM110444
                                    * THIS VERSION PUNCHES OFF-LINE ONLY.                               HM110445
                                    *                                                                   HM110446
                                    ********************************************************************HM110447
                         00006              ENTRY    BINPU                                              HM110448
                                    *                                                                   HM110449
     TRANSFER VECTOR
 CCC00  743146623460        (IOS)
 00001  746651623460        (WRS)
 CC002  745123303460        (RCH)
 C0003  746663233460        (WTC)
 00004  746625513460        (WER)
 0C005  746325623460        (TES)

 0C006  0634 00 1 00142     BINPU SXA    X1,1                                                       HM110450
 CC007  0634 00 2 00143           SXA    X2,2                                                       HM110451
 00010 -0500 60 4 00006           CAL*   6,4                                                        HM110452
 0C011  0622 00 0 00331           STD    140                                                        HM110453
 00012  0500 00 4 00001           CLA    1,4                  LOC OF ARRAY                          HM110454
 C0013  0621 00 0 00062           STA    ARRAY                                                      HM110455
 00014 -0500 60 4 00002           CAL*   2,4                  WORD COUNT                            HM110456
 0C015  0602 00 0 77776           SLW    END                  END=0 IF TRANSFER CARD                HM110457
```

```
00016  0402 00 0 00325          SUB     D1                                              HM110458
00017  0622 00 0 00066          STD     LCCN                                            HM110459
00020  0634 00 0 00061          SXA     CCOUNT,0                                        HM110460
00021  0500 60 4 00003          CLA*    3,4               SET UP CONTROL WORD           HM110461
00022  0771 00 0 00022          ARS     18                                              HM110462
00023 -0120 00 0 00025          TMI     *+2                                             HM110463
00024 -0501 00 0 00266          ORA     REL               ADD RELATIVE BIT              HM110464
00025 -0501 00 0 00334          ORA     IMAGE             7-9, WORD COUNT=22            HM110465
00026  0602 00 0 77740          SLW     CIMAGE            CONTROL WORD ESTABLISHED.     HM110466
                         *******************************************************************HM110467
                         *      TEST FOR FOURTH AND-OR FIFTH ARGUMENTS.                 HM110468
                         *      DETERMINE WHETHER ARGUMENT REFERS TO ID OR SEQ NUMBER   HM110469
                         *      AND SET CELLS FROM CALLING SEQUENCE.                    HM110470
                         *******************************************************************HM110471
00027  0774 00 2 00002          AXT     2,2                                             HM110472
00030 -0625 00 0 00302          STL     BLSEQ             SET BLSEQ TO ITS NORMAL STATE HM110473
00031 -0500 00 4 00004   G4     CAL     4,4               TEST FOR 4TH, 5TH ARGS        HM110474
00032 -0320 00 0 00265          ANA     MSKPDT                                          HM110475
00033  0322 00 0 00307          ERA     MSKTSX                                          HM110476
00034 -0100 00 0 00054          TNZ     G2                NO MORE TSXES                 HM110477
00035  0500 60 4 00004          CLA*    4,4                                             HM110478
00036 -0340 00 0 00262          LAS     BCI8                                            HM110479
00037  0020 00 0 00051          TRA     G3                BIG, THIS IS ID               HM110480
00040  0600 00 0 00302          STZ     BLSEQ             EQUAL, FLAG BLANK SEQ. NO.    HM110481
00041 -0100 00 0 00043          TNZ     *+2               IS SEQ NO NON-ZERO.           HM110482
T 00042 -0754 00 0 00000        PXD                       NO                            HM110483
00043 -0130 00 0 00000          XCL                       SMALL, THIS IS SEQ NO.        HM110484
00044  0634 00 4 00046          SXA     *+2,4                                           HM110485
00045  0074 00 4 00172          TSX     COSEQ,4           CONVERT SEQ NO TO BCD         HM110486
00046  0774 00 4 00000          AXT     **,4                                            HM110487
00047  0602 00 0 00267          SLW     SEQNO             SAVE                          HM110488
00050  1 77777 4 00053          TXI     G5,4,-1                                         HM110489
00051  0601 00 0 00305   G3     STO     BCDID                                           HM110490
00052  1 77777 4 00053          TXI     G5,4,-1           MOVE TO NEXT ARGUMENT         HM110491
00053  2 00001 2 00031   G5     TIX     G4,2,1            AT MOST 2 EXTRA ARGS.         HM110492
00054  0634 00 4 00144   G2     SXA     X4,4                                            HM110493
00055 -0520 00 0 77776          NZT     END               IS WORD COUNT ZERO            HM110494
00056  0020 00 0 00152          TRA     TRCD              MUST BE A TRANSFER CARD       HM110495
```

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                                    *                                                               HM110496
                                    ****************************************************************HM110497
                                    *     BUILD THE CARD IMAGE.                                     HM110498
                                    ****************************************************************HM110499
                                    *                                                               HM110500
   00057  0774 00 2 00026  NEXT    AXT    22,2                                                      HM110501
T  00060 -0754 00 0 00000          PXD                          CLEAR AC FOR CHECKSUM.              HM110502
   00061  0774 00 4 00000  COUNT   AXT    **,4                                                      HM110503
   00062  0560 00 4 00000  ARRAY   LDQ    **,4                  MOVE ARRAY INTO CORE.               HM110504
   00063 -0600 00 2 77770          STQ    CIMAGE+24,2                                               HM110505
   00064  0361 00 2 77770          ACL    CIMAGE+24,2           ACCUMULATE CHECKSUM FOR BODY.       HM110506
   00065  1 00001 4 00066          TXI    *+1,4,1                                                   HM110507
   00066  3 00000 4 00160  LOCN    TXH    OUT,4,**              FINISH WHEN SPECIFIED               HM110508
   00067  2 00001 2 00062          TIX    ARRAY,2,1             BY NO. WORDS DESIRED.(2,4)          HM110509
   00070  0634 00 4 00061  IN      SXA    COUNT,4               SET COUNT FOR NEXT LOOP.            HM110510
   00071  0361 00 0 77740          ACL    CIMAGE                ADD IN CONTROL WORD.                HM110511
   00072  0602 00 0 77741          SLW    CIMAGE+1              PUT CHECKSUM IN IMAGE.              HM110512
                                    *                                                               HM110513
                                    ****************************************************************HM110514
                                    *     EDIT THE IDENTIFICATION FIELD.                            HM110515
                                    ****************************************************************HM110516
                                    *                                                               HM110517
   00073 -0500 00 0 00267  EDIT    CAL    SEQNO                                                     HM110518
   00074  0560 00 0 00327          LDQ    L(1)                                                      HM110519
   00075 -0765 00 0 00022          LGR    18                                                        HM110520
   00076 -0500 00 0 00305          CAL    BCDID                                                     HM110521
   00077 -0763 00 0 00006          LGL    6                                                         HM110522
   00100 -0600 00 0 00326          STQ    IDLCD            SAVE FOR FINISHING.                      HM110523
   00101 -0130 00 0 00000          XCL                                                              HM110524
   00102  0634 00 1 00120          SXA    SV1,1                                                     HM110525
   00103  0774 00 2 00004          AXT    4,2                                                       HM110526
   00104  0774 00 4 00002          AXT    2,4                                                       HM110527
   00105  0774 00 1 00003  ABC     AXT    3,1                                                       HM110528
T  00106 -0754 00 0 00000          PXD                                                              HM110529
   00107 -0114 01 0 00230          CAQ    TAB,,1                                                    HM110530
   00110 -2 00001 1 00113          TNX    *+3,1,1                                                   HM110531
   00111  0767 00 0 00014          ALS    12                                                        HM110532
   00112  0020 00 0 00107          TRA    *-3                                                       HM110533
```

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BINPU ROUTINE TO WRITE COL BIN CARDS ON TAPE. FIBII                        4/20/62     PAGE 4

                                                                           HM110534
00113  0602 00 2 77734          SLW    LAST+4,2       COL BIN AT LAST TO LAST+3   HM110535
00114  1 77777 2 00115          TXI    *+1,2,-1                            HM110536
00115  2 00001 4 00105          TIX    ABC,4,1                             HM110537
00116  0560 00 0 00326          LDQ    IDLCD          FINISH W/SAVED C(MQ).       HM110538
00117  3 00000 2 00104          TXH    ABC-1,2,0                           HM110539
00120  0774 00 1 00000   SV1    AXT    **,1                                HM110540
                         *                                                 HM110541
                         ************************************************************HM110542
                         *      THE ENTIRE CARD IMAGE IS BUILT, WITH THE BODY         HM110543
                         *      AT CIMAGE THRU CIMAGE+23, AND ID AT LAST THRU LAST+3. HM110544
                         *      NOW ***** WRITE THE CARD ON TAPE. ********            HM110545
                         ************************************************************HM110546
                                                                           HM110547
00121  0761 00 0 00000   WRITE  NOP                                        HM110548
00122 -0500 00 0 00331   WRITE1 CAL    14D                                 HM110549
00123  0074 00 4 00000          CALL   (IOS)          ESTABLISH I/O FOR TAPE 14.  HM110550
00124  0522 60 0 00001          XEC*   $(WRS)                              HM110551
00125 -0774 00 4 00213          AXC    PUNCMD,4                            HM110552
00126  0522 60 0 00002          XEC*   $(RCH)                              HM110553
00127  0754 00 4 00000          PXA    0,4            SET (WER) FOR RETRY.        HM110554
00130  0621 60 0 00003          STA*   $(WTC)                              HM110555
00131  0074 00 4 00004   BPTES  TSX    $(WER),4                            HM110556
00132 -0500 00 0 00267          CAL    SEQNO                               HM110557
00133  0400 00 0 00327          ADD    L(1)           INCREMENT CARD COUNT.       HM110558
00134  0114 06 0 00215          CVR    TB1,,6                              HM110559
00135  0602 00 0 00267          SLW    SEQNO                               HM110560
00136  0520 C0 0 77776          ZET    END            TEST IF LAST CARD.          HM110561
00137  0020 00 0 00146          TRA    SWTCH             NOT THE LAST CARD....    HM110562
00140 -0500 00 0 00131          CAL    BPTES                               HM110563
00141  0602 60 0 00005          SLW*   $(TES)                              HM110564
00142  0774 00 1 00000   X1     AXT    **,1              ALL DONE. EXIT           HM110565
00143  0774 00 2 00000   X2     AXT    **,2                                HM110566
00144  0774 00 4 00000   X4     AXT    **,4                                HM110567
00145  0020 00 4 00005          TRA    5,4                                 HM110568
                         *                                                 HM110569
                         ************************************************************HM110570
00146 -0500 00 0 77740   SWTCH  CAL    CIMAGE            UPDATE THE CARD ORIGIN.  HM110571
00147  0361 00 0 00333          ACL    A22
00150  0602 00 0 77740          SLW    CIMAGE
```

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      BINPU ROUTINE TO WRITE COL BIN CARDS ON TAPE. FIBII                        4/20/62     PAGE 5
                                                                                                 HM110572
00151  0020 00 0 00057           TRA     NEXT                                                    HM110573
                          *******************************************************************HM110574
                          *                                                                      HM110575
00152  0774 00 2 00027    TRCD   AXT     23,2                    CLEAR REST OF                   HM110576
00153  0600 00 2 77770           STZ     CIMAGE+24,2             CARD IMAGE.                     HM110577
00154  2 00001 2 00153           TIX     *-1,2,1                                                 HM110578
00155  0500 00 0 00322           CLA     ZWC                     STORE ZERO WORD COUNT           HM110579
00156  0622 00 0 77740           STD     CIMAGE                                                  HM110580
00157  0020 00 0 00073           TRA     EOIT                                                    HM110581
                          *                                                                      HM110582
                          *******************************************************************HM110583
                          *                                                                      HM110584
00160  0600 00 0 77776    OUT    STZ     END                     WORD COUNT EXHAUSTED            HM110585
00161 -2 00001 2 00070           TNX     IN,2,1                  RETURN IF CARD IS FULL          HM110586
00162  0602 00 0 77777           SLW     COMMON                  SAVE CHECKSUM.                  HM110587
00163 -0754 00 2 00000           PXD     0,2                     CORRECT WORD COUNT              HM110588
00164  0402 00 0 77740           SUB     CIMAGE                                                  HM110589
00165  0622 00 0 77740           STD     CIMAGE                                                  HM110590
00166 -0500 00 0 77777           CAL     COMMON                  RETURN CHECKSUM.                HM110591
00167 -3 00000 2 00070           TXL     IN,2,0                                                  HM110592
00170  0600 00 2 77770           STZ     CIMAGE+24,2             CLEAR REST OF CARD.             HM110593
00171  1 77777 2 00167           TXI     *-2,2,-1                                                HM110594
                          *                                                                      HM110595
                          *******************************************************************HM110596
                          * THIS ROUTINE CONVERTS A BINARY INTEGER TO BCD. (4 DIGITS DECR-MQ)    HM110597
                          *******************************************************************HM110598
                          *                                                                      HM110599
T      00172 -0754 00 0 00000    COSEQ  PXD                                                      HM110600
00173 -0520 00 0 00302           NZT     BLSEQ                   TEST IF BLANKS DESIRED.         HM110601
00174  0020 00 0 00211           TRA     COSEQX                                                  HM110602
00175  0765 00 0 00022           LRS     18                      RIGHT ADJUST BIN INTEGER        HM110603
00176  0221 00 0 00332           DVP     TEN                                                     HM110604
00177  0601 00 0 77777           STO     COMMON                                                  HM110605
T      00200 -0754 00 0 00000           PXD                                                      HM110606
00201  0221 00 0 00332           DVP     TEN                                                     HM110607
00202  0767 00 0 00006           ALS     6                                                       HM110608
00203 -0602 00 0 77777           ORS     COMMON                                                  HM110609
T      00204 -0754 00 0 00000           PXD
```

```
                                                                             HM110610
00205  0221 00 0 00332           DVP    TEN                                  HM110611
00206  0767 00 0 00014           ALS    12                                   HM110612
00207 -0501 00 0 77777           ORA    COMMON      RIGHT ADJUSTED SEQ NO.   HM110613
00210  0020 00 4 00001           TRA    1,4                                  HM110614
00211 -0500 00 0 00306   COSEQX  CAL    BLANK       BLANK OUT SEQ. NO.       HM110615
00212  0020 00 4 00001           TRA    1,4                                  HM110616
                         *                                                   HM110617
                         ***************************************************HM110618
                         *                                                   HM110619
00213 -0 00030 0 77740   PUNCHD  IOCP   CIMAGE,0,24                          HM110620
00214  0 00003 0 77730           IOCD   LAST,0,3                             HM110621
                         *                                                   HM110622
                         * TABLE FOR BCD ADDITION OF 1 TO C(ACC)             HM110623
                         *                                                   HM110624
00215  0000 00 0 00215   TB1     HTR    TB1                 0                HM110625
00216  0100 00 0 00215   TB      TZE    TB1                 1                HM110626
00217  0200 00 0 00215           MPY    TB1                 2                HM110627
00220  0300 00 0 00215           FAD    TB1                 3                HM110628
00221  0400 00 0 00215           ADD    TB1                 4                HM110629
00222  0500 00 0 00215           CLA    TB1                 5                HM110630
00223  0600 00 0 00215           STZ    TB1                 6                HM110631
00224  0700 00 0 00215           CPY    TB1                 7                HM110632
00225  1 00000 0 00215           TXI    TB1                 8                HM110633
00226  1 10000 0 00215           TXI    TB1,0,4096          9                HM110634
00227  0000 00 0 00216           HTR    TB                  0 WITH CARRY     HM110635
                         * TABLES FOR BCD-COL. BIN. CONVERSION               HM110636
                         * HOLES ARE FILLED IN WITH CONSTANTS                HM110637
00230 +000000001000      TAB     OCT    1000,400,200,100,40,20,10,4,2,1
00231 +000000000400
00232 +000000000200
00233 +000000000100
00234 +000000000040
00235 +000000000020
00236 +000000000010
00237 +000000000004
00240 +000000000002                                                          HM110638
00241 +000000000001      MSK2CH  OCT    777777770000,102,42
00242 -377777770000
```

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      BINPU ROUTINE TO WRITE COL BIN CARDS ON TAPE. FIBII                              4/20/62    PAGE 6

      00205  0221 00 0 00332           DVP     TEN                                            HM110610
      00206  0767 00 0 00014           ALS     12                                             HM110611
      00207 -0501 00 0 77777           ORA     COMMON          RIGHT ADJUSTED SEQ NO.         HM110612
      00210  0020 00 4 00001           TRA     1,4                                            HM110613
      00211 -0500 00 0 00306   COSEQX  CAL     BLANK           BLANK OUT SEQ. NO.             HM110614
      00212  0020 00 4 00001           TRA     1,4                                            HM110615
                               *                                                              HM110616
                               ***************************************************************HM110617
                               *                                                              HM110618
      00213 -0 00030 0 77740   PUNCMD  IOCP    CIMAGE,0,24                                    HM110619
      00214  0 00003 0 77730           IOCD    LAST,0,3                                       HM110620
                               *                                                              HM110621
                               * TABLE FOR BCD ADDITION OF 1 TO C(ACC)                        HM110622
                               *                                                              HM110623
      00215  0000 00 0 00215   TB1     HTR     TB1             0                              HM110624
      00216  0100 00 0 00215   TB      TZE     TB1             1                              HM110625
      00217  0200 00 0 00215           MPY     TB1             2                              HM110626
      00220  0300 00 0 00215           FAD     TB1             3                              HM110627
      00221  0400 00 0 00215           ADD     TB1             4                              HM110628
      00222  0500 00 0 00215           CLA     TB1             5                              HM110629
      00223  0600 00 0 00215           STZ     TB1             6                              HM110630
4     00224  0700 00 0 00215           CPY     TB1             7                              HM110631
ID    00225  1 00000 0 00215           TXI     TB1             8                              HM110632
      00226  1 10000 0 00215           TXI     TB1,0,4096      9                              HM110633
      00227  0000 00 0 00216           HTR     TB              0 WITH CARRY                   HM110634
                               * TABLES FOR BCD-COL. BIN. CONVERSION                          HM110635
                               * HOLES ARE FILLED IN WITH CONSTANTS                           HM110636
      00230 +000000001000      TAB     OCT     1000,400,200,100,40,20,10,4,2,1                HM110637
      00231 +000000000400
      00232 +000000000200
      00233 +000000000100
      00234 +000000000040
      00235 +000000000020
      00236 +000000000010
      00237 +000000000004
      00240 +000000000002
      00241 +000000000001
      00242 -377777770000      MSK2CH OCT     777777770000,102,42                             HM110638
```

```
   00243 +000000000102
   00244 +000000000042
   00245 +000000000000     IDI23 OCT  0,0,0                                                HM110639
   00246 +000000000000
   00247 +000000000000
   00250 +000000004000           OCT  4000,4400,4200,4100,4040,4020,4010,4004,4002,4001   HM110640
   00251 +000000004400
   00252 +000000004200
   00253 +000000004100
   00254 +000000004040
   00255 +000000004020
   00256 +000000004010
   00257 +000000004004
   00260 +000000004002
   00261 +000000004001
   00262  106060606060     BCI8  BCI  1,8                                                  HM110641
   00263 +000000004102           OCT  4102,4042                                            HM110642
   00264 +000000004042
   00265 -3 77777 7 00000  MSKPDT TXL 0,7,-1                                               HM110643
A  00266  0400 00 0 00000  REL   ADD                                                       HM110644
   00267  606060606060     SEQNO BCI  1,                                                   HM110645
   00270 +000000002000           OCT  2000,2400,2200,2100,2040,2020,2010,2004,2002,2001   HM110646
   00271 +000000002400
   00272 +000000002200
   00273 +000000002100
   00274 +000000002040
   00275 +000000002020
   00276 +000000002010
   00277 +000000002004
   00300 +000000002002
   00301 +000000002001
   00302  0 00000 0 00000  BLSEQ                                                           HM110647
   00303 +000000002102           OCT  2102,2042                                            HM110648
   00304 +000000002042
   00305  606060606060     BCDID BCI  1,                                                   HM110649
   00306  606060606060     BLANK BCI  1,                                                   HM110650
   00307  0074 00 0 00000  MSKTSX TSX ,0                                                   HM110651
   00310 +000000000000           OCT  0,1400,1200,1100,1040,1020,1010,1004,1002,1001      HM110652
```

```
00311 +000000001400
00312 +000000001200
00313 +000000001100
00314 +000000001040
00315 +000000001020
00316 +000000001010
00317 +000000001004
00320 +000000001002
00321 +000000001001
00322 +000500000000      ZWC    OCT      000500000000        ZERO WORDS FOR TCD                HM110653
00323 +000000001102             OCT      1102,1042                                             HM110654
00324 +000000001042
00325  0 00001 0 00000    D1             0,0,1                                                 HM110655
00326  0 00000 0 00000    IDLCD  PZE                                                           HM110656
00327  0 00000 0 00001    L(1)   PZE      1                                                     HM110657
00330  0 00000 0 00005    SA     PZE      5                                                     HM110658
00331  0 00014 0 00020    14D    PZE 16,,12                                                    HM110659
00332 +000000000012       TEN    DEC      10                                                    HM110660
00333  0000 00 0 00026    A22    HTR      22                                                    HM110661
00334 +000526000000       IMAGE  OCT      000526000000        CONTROL WORD SKELETON             HM110662
                  77777   COMMON EQU      -1                                                    HM110663
                  77740   CIMAGE EQU      -32                                                   HM110664
                  77730   LAST   EQU      -40                                                   HM110665
                  77776   END    SYN      COMMON-1                                              HM110666
                                 END                                                           HM110667
```

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 BINPU ROUTINE TO WRITE COL BIN CARDS ON TAPE. FIBII                    4/20/62    P
                     POST PROCESSOR ASSEMBLY DATA

 335 IS THE FIRST LOCATION NOT USED BY THIS PROGRAM

REFERENCES TO DEFINED SYMBOLS
   330      5A
   325      D1     16
    54      G2     34
    51      G3     37
    31      G4     53
    53      G5     50,   52
    70      IN    161,  167
   216      TB    227
   142      X1      6
   143      X2      7
   144      X4     54
   331     140     11,  122
   333     A22    147
   105     ABC    115,  117
 77776     END     15,   55,  136,  160
   160     OUT     66
   266     REL     24
   120     SV1    102
   230     TAB    107
   215     TB1    134,  215,  216,  217,  220,  221,  222,  223,  224,  225,  226
   332     TEN    176,  201,  205
   322     ZWC    155
   262    BCIB     36
    73    EDIT    157
 77730    LAST    113,  214
    66    LOCN     17
   327    L(1)     74,  133
    57    NEXT    151
   152    TRCD     56
    62   ARRAY     13,   67
   305   BCDID     51,   76
     6   BINPU      0
   306   BLANK    211
   302   BLSEQ     30,   40,  173
```

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BINPU ROUTINE TO WRITE COL BIN CARDS ON TAPE. FIBII                                   4/20/62     P
                           POST PROCESSOR ASSEMBLY DATA

    131  BPTES    140
    172  COSEQ     45
     61  COUNT     20,    70
    245  (DI2)
    326  IDLCD    100,   116
    334  IMAGE     25
    267  SEQNO     47,    73,   132,   135
    146  SWTCH    137
    121  WRITE
      0  (IOS)    123
      2  (RCH)    126
      5  (TES)    141
      4  (WER)    131
      1  (WRS)    124
      3  (WTC)    130
  77740 CIMAGE     26,    63,    64,    71,    72,   146,   150,   153,   156,   164,   165,   170,   213
  77777 COMMON    162,   166,   177,   203,   207,   335
    211 COSEQX    174
    242 MSK2CH
    265 MSKPDT     32
    307 MSKTSX     33
    213 PUNCMD    125
    122 WRITE1

NO ERROR IN ABOVE ASSEMBLY.
```

• CATA HM110668

ENTRY POINTS TO SUBROUTINES REQUESTED FROM LIBRARY,

(FPT) (TSHM) (RTN) (STHM) (FIL) SORT (IOS) (WRS) (RCH)
(WTC) (WER) (TES)

MACHINE TAPE	TOTAL WRITES	TOTAL READS	NOISE RECORDS WRITING	NOISE RECORDS READING	TOTAL REDUNDANCIES WRITING	TOTAL REDUNDANCIES READING	POSITIONING ERRORS
A 1	0	530	0	0	0	0	0
B 2	591	646	0	0	0	0	0
B 3	125	153	0	0	0	0	0
A 4	450	535	0	0	0	0	0
A 2	0	677	0	0	0	0	0
A 3	579	3	0	0	0	0	0
B 4	159	162	0	0	0	0	0

EXECUTION 12.525

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Aerospace Corporation, El Segundo, California.
AERODYNAMIC INFLUENCE COEFFICIENTS FROM PISTON THEORY: ANALYTICAL DEVELOPMENT AND COMPUTATIONAL PROCEDURE, prepared by W.P. Rodden, E.F. Farkas, H.A. Malcom and A. M. Kliszewski. 15 August 1962. [90] p. incl. illus.
(Report TDR-169(3230-11)TN-2;SSD-TDR-62-75)
(Contract AF 04(695)-169) Unclassified report

In this report we present a method for calculating the aerodynamic influence coefficients (AICs) based on third-order piston theory with an optional correction to agree with Van Dyke's quasi-steady second-order theory. The AICs are computed assuming the airfoil to have a rigid chord with or without a (rigid chord) control surface. The influence coefficients relate the surface deflections to the aerodynamic forces through the following definitions in the oscillatory case, $\{F\} = \rho\omega^2 b_r^2 s[C_h]\{h\}$ and in the steady

(over)

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case, $\left|F_s\right| = (1/2)\rho V^2(S/\bar{c})\left[C_{hs}\right]\left|h\right|$. The piston theory is limited to high Mach number (or high reduced frequency), but Van Dyke's quasi-steady correction extends the validity to some lower supersonic Mach number at low reduced frequency. The Aerospace IBM 7090 Computer Program Number HM11 provides the AICs from this theory in both a printed and an optional punched-card output format. The program capacity is 25 surface strips, 15 Mach numbers, and 20 reduced velocities for each Mach number.

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In this report we present a method for calculating the aerodynamic influence coefficients (AICs) based on third-order piston theory with an optional correction to agree with Van Dyke's quasi-steady second-order theory. The AICs are computed assuming the airfoil to have a rigid chord with or without a (rigid chord) control surface. The influence coefficients relate the surface deflections to the aerodynamic forces through the following definitions in the oscillatory case, $\{F\} = \rho\omega^2 b_r^2 s[C_h]\{h\}$ and in the steady

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Aerospace Corporation, El Segundo, California. AERODYNAMIC INFLUENCE COEFFICIENTS FROM PISTON THEORY: ANALYTICAL DEVELOPMENT AND COMPUTATIONAL PROCEDURE, prepared by W.P. Rodden, E.F. Farkas, H. A. Malcom and A. M. Kliszewski. 15 August 1962. [90] p. incl. illus.
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case, $\{F_s\} = (1/2)\rho V^2(S/\bar{c})\,[C_{hs}]\,\{h\}$. The piston theory is limited to high Mach number (or high reduced frequency), but Van Dyke's quasi-steady correction extends the validity to some lower supersonic Mach number at low reduced frequency. The Aerospace IBM 7090 Computer Program Number HM11 provides the AICs from this theory in both a printed and an optional punched-card output format. The program capacity is 25 surface strips, 15 Mach numbers, and 20 reduced velocities for each Mach number.

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